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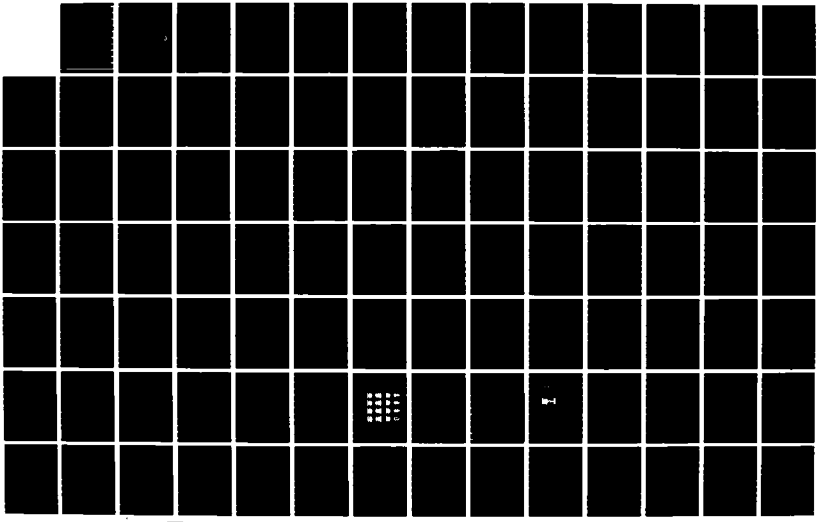

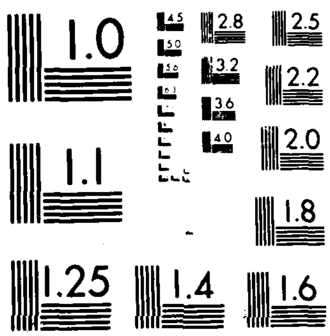

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THE EFFECT OF TWO MAXILLARY SPLINT OCCLUSAL GUIDANCE PATTERNS ON THE ELECTROMYOGRAPHIC ACTIVITY OF THE JAW CLOSING MUSCLES

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The University of Texas Graduate School of Biomedical Sciences at San Antonio

Supervising Professor: John D. Rugh

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A

THESIS

Presented to the Faculty of

The University of Texas Graduate School of Biomedical Sciences

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in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Garbeth Sheldon Graham, B.S., D.D.S.

San Antonio, Texas

May 1986

THE EFFECT OF TWO MAXILLARY SPLINT OCCLUSAL GUIDANCE PATTERNS ON THE ELECTROMYOGRAPHIC ACTIVITY OF THE JAW CLOSING MUSCLES

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APPROVED:

A. J. Gnarino, Ph.D.
Dean

DEDICATION

I dedicate this Thesis to our Creator Who has given us a world of order that can be explored by rational investigation; He provides purpose and strength for the many tasks of daily life.

Not by might
nor by power,
but by my Spirit.
Says the LORD Almighty.

Zechariah 4:6b (NIVB)

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I want to acknowledge the United States Air Force Dental Corps which provided support for my graduate education in periodontics. The opportunity to further my skills and learning in dentistry is greatly appreciated.

Finally, it is conventional to thank one's wife for aid and comfort. In my case her patience and understanding transcend conventional language.

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relationship between neuromuscular function and the mechanics of tooth contours involves complex interactions. Early writings on the subject tended to be essays based on clinical observations. Following a period of mechanical influences and the development of articulators, a period of anthropologic observations led to a conclusion that the canine and premolar teeth have special proprioceptive characteristics. These principles have been widely accepted in clinical dental practice with a minimum of controlled experimental support.

This present study recorded electromyographic (EMG) activity of jaw closing muscles. Electronic methods were used to quantify the activity and to compare canine guidance with first molar guidance. Integrated bilateral surface EMG measurements of masseter and anterior temporalis muscles of ten subjects were made using four Grass model 7DAF preamplifiers and J & J integrators. Two silver/silver chloride surface electrodes were placed over each masseter and anterior temporalis muscle. Occlusal guidance for right lateral excursive movement was alternated between canine and first molar on a maxillary acrylic splint. Subjects were monitored while clenching sequentially in three positions. These positions were (1) centric occlusion, (2) movement into right lateral and (3) right excursive position (canine to canine lateral position). EMG scores were recorded for five sequences of clenching on each randomly selected

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occlusal pattern. The subjects were instructed to begin clenching in centric occlusion, move into right lateral while clenching and continue clenching in right lateral excursive. These commands were given at the 0, 5 and 10 second points of each 15 second sequence. A total of fifteen one second samples of the EMG activity were stored and printed by an AIM 65 computer. The middle three one-second samples for each of the three five second phases of the sequence were averaged to give an EMG score for the activity of the phase. These scores were used for paired t-test analysis of mean total muscle performance for the two guidance patterns and for an analysis of variance among the four muscle groups. These analyses were done on a DEC VAX-11 computer using Department of Biomathematics, University of California software.

In general, jaw muscle activity was reduced during lateral movement and excursive position clenching. This was found to be true on both canine guidance and first molar guidance patterns. There was no statistically significant difference between canine and first molar guidance patterns. In this study there was considerable variance in the actual EMG scores achieved by each subject. Therefore to control for such subject variability the mean raw EMG scores were used to calculate intrasubject percentages of change. With clenching in centric occlusion representing 100% effort, reductions in EMG activity

were calculated for clenching during the movement and excursive phases. These percentage reductions were used to compare muscle activity on the two guidance patterns. Average reductions of EMG activity for the movement phase were 81.8 ±14.0% on splints with canine guidance and 81.6 ±19.2% on splints with first molar guidance. Average reductions of EMG activity in the excursive phase were 44.7 ±26.7% on splints with canine guidance and 42.6 ±29.7% on splints with first molar guidance. There was no statistically significant difference in these reductions for the same clenching position on the two guidance patterns of canine and first molar.

These results do not support the premise that the canine possesses special neurophysiologic characteristics for excursive guidance. The greater reduction of EMG activity observed in the movement phase may be a prerequisite for maintaining movement. The similar magnitude of EMG reduction observed for the two occlusal patterns may be due to peripheral or central neural influences. One peripheral influence affecting the EMG activity might be the number of contacts rather than which tooth is contacting. A central factor might be the reflex inhibition of the musculature by centra neural mechanisms that generate masticatory and other jaw movements. Extrapolation of these results to clinical splint practice must be tempered by the study's limitations. An obvious limitation is that the

measurements were taken in the artificial environment of the laboratory on subjects who were healthy individuals and not patients actively seeking care for bruxism or facial pain.

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and Ash, 1981). While this reflex has not been clearly demonstrated, some have reported a decrease in muscle activity for excursive movements guided by the canines (Schaerer, et al., 1967, Schweitzer, 1961, Yemm, 1976, Williamson and Lundquist, 1983).

Actual study of the effect of canine guidance upon the musculature has centered upon chewing patterns (Yaeger, 1978). Such studies of the chewing cycle have employed various levels of technology ranging from cinematographic methods (Hildebrand, 1931) to recent incorporation of computer analysis of the muscle electromyographic (EMG) activity (Hannam, 1977). But a lack of understanding continues to exist concerning "the precise association between EMG activity in the muscles of mastication, patterns of jaw movement during chewing, and dental occlusion" (Hannam, 1981).

Most recently an experimental investigation was done to improve the understanding of this association between masticatory muscle EMG activity and dental occlusion and to test D'Amico's conclusions about the advantage of canine guidance (Williamson and Lundquist, 1983). These investigators examined masseter and anterior temporalis muscle activity while varying subjects' occlusal guidance. Four of the five subjects had positive histories for temporomandibular joint pain and dysfunction. In

this study an occlusal splint with canine guidance provided anterior guidance. EMG activity was recorded with surface electrodes while the subjects went through excursive movements with and without a splint in place. The subject's EMG activity with the canine guidance splint was compared to the EMG activity with the splint in place but the canine guidance removed and without the splint in place. The resulting EMG tracings were compared visually. These investigators report marked reductions in the amplitude of electromyographic activity when anterior guidance was provided by the splint with canine guidance. They conclude "that only when posterior disclusion is obtained by an appropriate anterior guidance can the elevating activity of the anterior temporalis and masseter muscles be reduced".

This finding that canine guidance relaxes the anterior temporalis and masseter muscles during lateral movement and clenching is very significant. Confirmation of this finding provides a rationale for the employment of canine guidance for patients being treated for parafunctional habits or receiving occlusal reconstructions. However, the Williamson and Lundquist study has major problems. The study involved inadequate quantification of the observed EMG activity and inadequate controls. While the EMG tracings graphically illustrated a decreased muscle activity during clenching in excursive movements there was no quantification of this change. No numerical

quantification of the EMG activity was reported. Analysis of the changes in the EMG activity consisted only of a visual assessment of the amplitude of the tracings. The experimental variable of canine guidance was compared to two separate and distinct controls but neither control was described in detail. Guidance pattern details of which specific teeth contacted which areas of the splint when the canine guidance was removed were lacking. Details of which specific teeth contacted to provide the subject's natural occlusal guidance were also lacking. Plus the subjects had positive histories of pain and dysfunction and it is thus not clear that one can generalize these results to healthy subjects.

The purpose of this study is to determine if canine guidance as compared to guidance from another individual tooth has a unique effect upon masticatory muscle EMG activity during lateral movement and lateral excursive position clenching. Numerical quantification of EMG data will be subjected to statistical analysis to test for a difference between two distinct and controlled occlusal guidance patterns in non-patient subjects. The literature review includes a discussion of the history of the development of the clinical concepts of occlusal guidance with emphasis upon the role of anterior guidance. Such background information also illustrates the adoption of scientific methodology for the study of occlusion. Experimental

observations of masticatory muscle function are next reviewed with emphasis on the proprioceptive inputs, reflex pathways, and other neural control mechanisms.

The present study examines the effects of two occlusal guidance patterns, specifically canine guidance and its antithesis (Ramfjord, 1984), first molar guidance. A within subject design is employed with a maxillary splint providing the occlusal guidance in a counterbalanced approach. Bilateral masseter and anterior temporalis EMG activity are recorded and quantified numerically during clenching in centric occlusion, movement into right lateral position, and clenching in right lateral excursive position. The percent reductions of EMG activity for movement and excursive clenching on canine guidance are compared with those observed with first molar guidance. The results will be related to the neurologic control of the muscles of mastication.

II. LITERATURE REVIEW

A. The Development of Occlusal Interest

Stedman's Medical dictionary defines "occlusion" as the act of closing or the state of being closed. In dentistry the word occlusion takes on added meaning. The Glossary of Prosthodontic Terms (Adisman, 1977) defines occlusion as that relationship between occlusal surfaces of the maxillary and mandibular teeth when they are in contact. Occlusion also refers to the study of how tooth contacts influence neuromuscular function and parafunction. Dentistry has not always been concerned with how the teeth mesh. The early concerns of dental treatment were directed towards problems with materials. Only in the past century after addressing the elementary problems of materials was occlusion given considerable attention.

Records of dental treatment date back to the fourth or fifth century B.C. with the first dental prostheses believed to have been constructed in Egypt about 2,500 B.C. (Weinberger, 1948). Such prosthesis involved the wiring of tooth substitutes to adjacent teeth. Tooth substitutes made of ivory, gold, brass and wood have been discovered in mummies. Little progress in prosthetic dentistry was recorded until the eighteenth century

when Pierre Fauchard developed improved means of attaching artificial teeth to remaining roots (Guerini, 1909, Weinberger, 1948). Since human teeth were scarce, costly, and difficult to obtain, the profession sought satisfactory substitutes. In 1774 Duchateau, an apothecary, began experimenting with minerals. His work lead to Dubois de Chemant's successful fabrication of porcelain dentures in 1787. Improvements in materials continued with the perfection of individual porcelain teeth and the development by Charles Goodyear (1855) of vulcanite denture bases (Johnson, 1959).

During this same time, attention was just beginning to be directed toward how the teeth should mesh. This interest in occlusion was spurred by the development of mechanical means of articulation. While the first articulator was invented by J.B. Gariot in 1805, the first anatomical articulator was patented by Evans in 1840. But it was not until 1848 that Bonwill developed the first satisfactory instrument (Johnson, 1959). With these articulators the mechanics of occlusion became a major interest in dentistry.

Karolyi is credited with suggesting in 1901 that tooth contacts or occlusion was an etiologic factor in periodontal disease (Waerhaug, 1955). With this observation dentistry began to investigate the biologic implications of occlusion. While the relationship of occlusion to periodontal disease continues to be

debated, other biologic aspects have been suggested. Ramfjord (1961) in an electromyography study of 34 bruxism patients indicted occlusion as an etiologic factor in parafunctions like bruxism. Others (Smith, 1978, Kaufman, 1980) have done experiments suggesting that occlusion can even affect skeletal muscle strength and athletic performance. Occlusion has now become a central concern for all the clinical disciplines within dentistry.

B. The Development of Theories of Occlusion

Ramfjord (1971) has divided the concepts of occlusion into three groups to facilitate discussion. These three groups are the orthodontic concept, the prosthetic concept, and the dynamic individual occlusion concept.

He notes that historically two of these concepts of occlusion have dominated dentistry. First there was the orthodontic concept of a static cusp and fossa relationship. The genesis of this concept was in the work of Angle (1899). It was believed that there was a presumed tooth to tooth relationship that was normal for the natural dentition. Other relationships were malocclusions that required treatment (Ramfjord, 1984). Gysi (1910) is credited with adding a functional element to this concept of "ideal occlusion." This concern for function led to the second concept, the prosthetic concept of "balanced

occlusion." In the prosthetic concept functional stability and effectiveness of removable dentures are enhanced by bilateral tooth contacts in lateral and protrusive excursions. This prosthetic concept has had its greatest impact in the realm of restorative dentistry. During the 1950's and 1960's a third concept emerged in a response to some of the perceived short comings of the prosthetic concept. This concept involves a dynamic individual occlusion wherein the criteria for diagnosis and treatment are "based upon the evaluation of the health and function of each individual's masticatory system" (Ramfjord, 1971).

Ross (1970) has divided concepts of occlusion similarly to Ramfjord's grouping but labeled them "morphologic occlusion", "balanced occlusion", and "functional occlusion" respectively. While all of these concepts influence the restorative treatment of patients' dentitions, what Ramfjord labeled the prosthetic concept has had the major impact.

Bonwill, who is credited with developing the first anatomical articulator, is also credited with first bringing the subject of occlusion to the attention of dentists (Thomson, 1975). He wrote in 1887 that he was "fully persuaded that of all that constitutes dentistry proper, the mechanical forms the basis." He observed skulls and found that the two condyles form an equilateral triangle of four inch sides with the incisal

contact point of the lower central incisors. This finding was the springboard to the development of his articulator. Gysi's (1910) thoughts on occlusion were heavily influenced by Bonwill (Thomas, 1975). He also chose the development of articulators as the means to address the subject of occlusion. Monson (1932) took this geometric view to its height with his proposed enhancements of Von Spee's theory that the center of a sphere with a four inch radius is equidistant from the occlusal surfaces of the posterior teeth and centers of the condyles. "The relationships between the angles of the condylar movements and those of the teeth both anterior and posterior have been a preoccupation of mathematically minded dentists for nearly a century" (Thomas, 1975). Such theoretical thoughts have been well developed and used in reconstructive techniques (Mann and Pankey, 1960) but with a notable lack of controlled experimental testing.

The close relationship of the development of the articulators and the prosthetic concept of occlusion is well illustrated by an address given by a laboratory technician and engineer to the Sixty-Seventh Annual Session of the American Dental Association (Hanau, 1926). This lecture outlined the essentials of occlusion as related principally by the articulator. He suggested that the factors governing the occlusion are condylar guidance, tooth alignment, incisal guidance, relative cusp height, and denture position. While he

emphasized the mechanical approach to occlusion, he cautioned "it is important that the mechanics be in compliance with physiologic requirements".

In 1926, B.B. McCollum founded the Gnathologic Society of California (Weisgold, 1973). In 1929 McCollum wrote that "the chewing function may well be called the master function of the mouth". With the clinical hypothesis that the mandible opens and closes on a fixed axis of rotation (McCollum, 1939), McCollum, Stuart and Stallard formulated the main precepts of gnathology (Stallard, 1945). These beliefs were based upon clinical experience and not well controlled experimental observations. Originally this group felt that balanced occlusion was required. Balanced occlusion is achieved when there is simultaneous, bilateral contact of both anterior and posterior teeth during eccentric movements of the mandible. This basic assumption that the mandibular teeth move in contact with the maxillary teeth in various eccentric positions during incision and mastication had been advanced for over a century and governed the direction and character of the search on the problem of occlusion (Jankelson, 1955). With time, many of the proponents of this idea noted excessive wear of restorations and out of this grew the canine protected occlusion concepts. Moving from the balanced occlusion concept, Stallard and Stuart (1963) eventually wrote that "organic occlusion reduces as much as possible the sliding of the teeth".

Illustrating how the dentists' workload has influenced the concepts of occlusion is a personal communication (Weisgold, 1973) from Stallard: "Perhaps the main excitant (i.e. the genesis of Gnathology) was the reaction of restorative dentists to the focal infection theory which led to such wholesale destructions of the eating abilities of the mouth. McCollum and his associates were out to find how to treat the gnathic organ so that the patient could have restored, as fully as possible, the eating function of the mouth." The work load of the time consisted of extensive tooth replacements by partial and complete removable dentures which function much differently than the natural dentition.

As the goals of dentistry changed to the preservation of the natural dentition, questions arose about the appropriateness of applying complete denture occlusion to the natural dentition. An East coast dentist, C.H. Schuyler, is credited with developing the major theoretical concerns for the natural dentition (Ramfjord and Ash, 1983). Schuyler (1947) began his writings supporting balanced occlusion. By 1963 he was suggesting anterior guidance in the natural dentition. With time, this idea of an anterior guidance to avoid balanced occlusion was gaining acceptance among dentists (Weisgold, 1973). His perception of functional occlusion is embodied today by the Pankey Institute's advocacy of the functionally generated path for restorative

procedures.

Also during this time there was a question concerning what influence the shape and movement of the condyles and the occlusion had upon each other (Monson, 1932). One group held that the shape and movement of the condyles determined the occlusion of the teeth. Another group held that the occlusion of the teeth is the dominant guiding factor which determines the shape and movement of the condyles in the glenoid fossa. Using an anthropologic method of analysis, Monson concluded that while the condyles guide the mandible to the first contact of the teeth, the major guidance is the teeth and that a permanent balance of the occlusion of the teeth cannot be maintained without a muscular balance of the mandible.

Not until Posselt's work in the early fifties was there any rigorous scientific testing or clinical trials of occlusal concepts. While Hildebrand (1931) made the first recordings of mandibular border movements, Posselt (1952) used the technique to study mandibular closure in young subjects with "clinically optimal occlusion." He found that the jaw closes into a position of maximum tooth contact (centric occlusion) and not the posterior border position of the Gnathologists' stable hinge axis (centric relation).

Cohen (1956) studied the effects of condylar guidance and anterior guidance with a mechanical device that produces tracings of the paths of motion of the condyles and teeth. His subject was a "well developed, healthy 25 year old woman." Tracings were made at varying vertical openings and overlayed for comparison. He found that the tracings of the condylar region were constant and identical and that the tracings of the anterior region were decidedly different. His conclusion was that the paths of movement of the mandible are governed by the condylar guidance and the anterior guidance and that since the condylar guidance is fixed only the anterior guidance can be altered.

Weinberg (1959) summarized this issue with an anatomical analysis of the guidance systems of the mandible in an essay devoid of experimental data. He concluded that the basic clinical procedures must produce a harmonious relationship (not defined) of the incisal guidance, the muscle complex, and the condylar paths and that the muscle complex and incisal guidance are functionally interrelated. Thus the purely mechanical view of occlusion was becoming replaced by a more physiologic view. The incisal guidance or anterior guidance was appreciated as a cofactor with the muscular complex in guiding mandibular movements. The foundation for understanding occlusion was beginning to shift away from that of clinical essay to experimental study and clinical trial.

C. The Role of Anterior Guidance

Anterior guidance involves incisal and canine guidance. It is the paths on the lingual surfaces of maxillary teeth along which the mandibular anterior teeth function through all ranges of function (Dawson, 1974). The prospective role anterior guidance plays in the health of the masticatory organ has been discussed considerably. The scientific basis for the various positions taken in these discussions has varied greatly. While some have written essays espousing the benefits of anterior guidance (Weinberg, 1959, Jones, 1963, Schuyler, 1963, Alexander, 1967) few have attempted controlled experimental studies (Jemt, et al., 1982, Williamson and Lundquist, 1983, Graham and Rugh, 1984). As part of the anterior guidance, the canines can guide the mandibular movements during lateral excursions. With excursive movements, if the premolars and molars join the canines in guiding the mandible, group guidance is in effect. Benefits have been claimed for both lateral guidance patterns. Proposed advantages of canine guidance can be divided into mechanical and non-mechanical benefits.

1. Mechanical Benefits

Some mechanical benefits attributed to anterior guidance include the distribution of forces and the determination of

posterior tooth occlusal contours. This distribution of forces to teeth anterior to the masseter muscles is advocated by Weinberg (1959), Schuyler (1963), Ramfjord and Ash (1971, 1981), and Dawson (1974). These authors also review the influence that the anterior guidance has upon the posterior contours. Such conclusions are based upon observations of the mechanics and geometry of articulators and not on experimental data.

In contrasting the role of the anterior teeth in natural and artificial dentitions, Schuyler (1959) noted that in dentures the anterior teeth do not contact during centric occlusion and that three point contacts in all eccentric positions are essential for the maximum functional stability of the dentures. This provided for the most favorable distribution of stress. Relying on extensive experience as a reconstructive dentist, he suggested that in the natural dentition the anterior teeth do contact in centric occlusion and that balancing contacts in the eccentric positions seem to be not only nonessential but are a common contributing cause of periodontal and temporomandibular disease. This mechanical view also holds that the anterior teeth by establishing the incisal guidance determine the posterior occlusal contours.

2. Non Mechanical Benefits

Non-mechanical advantages from anterior guidance have

also been suggested. In a study of 100 patients, Goldstein, (1979) concluded that the teeth of mouths with canine-protected occlusions (canine guidance) had significantly lower mean periodontal disease index scores than the teeth of mouths having progressive disclusion or group guidance.

The main non-mechanical benefit claimed (D'Amico, 1955) has been a "relaxation of the musculature". There is an assumption that during lateral excursive movements anterior guidance, specifically canine guidance, reflexly decreases tension of the temporal and masseter muscles. Because of this belief, excursive guidance on the canine or anterior teeth (or both) is frequently sought for occlusal disengagement splints (Ramfjord and Ash, 1981, Clark, 1984). The origin of this assumption can be traced to the essays of D'Amico (1955, 1958, 1961, 1965). No experimental tests of these assumptions were provided. Only after over two decades of clinical usage have the concepts been tested in a controlled manner.

In an effort to disprove the theory of "balanced occlusion" D'Amico published a series of articles in the late 1950's (1955, 1958) concerning the importance and role of the canine teeth. After an extensive review of the anthropologic theories on the origin and development of man's dentition and general clinical observations, he arrived at the previously mentioned mechanical and non-mechanical benefits (1955). His

observations came from skull studies of Indian, Peruvian, and Egyptian specimens in the University of California Anthropology Museum and field work with the Maidu Indians of Placer County California. He stated that "the overbite and interlocking relation of the upper canines is the natural articulation of those teeth and common to all primates, including man. Their main function during mastication is to guide the mandible into centric relation in a medial vertical direction so as to prevent the contact of the remaining opposing teeth until they meet in centric occlusion." Beyond this mechanical view, he reported that "clinical evidence of the effectiveness of the periodontal proprioceptor impulses of the canine teeth can be observed by studying the sequence of the loss of the natural teeth during the adult stages of life. Invariably, in the upper arch, the canine teeth are the last to be extracted; in the lower arch, almost consistently it is the canines and first premolars, these usually being the very last to be lost" (1958). Thus he concluded that besides a mechanical function, "the canine teeth also have a unique function. They are extremely sensitive organs. When their opponents come in contact during attempted eccentric movements of the mandible they transmit in a greater degree than any other teeth the desirable periodontal proprioceptor impulses to the muscles of mastication, reducing muscular tension and thereby reducing the magnitude of the applied force" (D'Amico, 1955). This conclusion was not based on controlled experimental data but on the observation that the canine teeth are clinically

durable.

In a later article reviewing his observations concerning the theory of balanced occlusion, the evolution of natural teeth, and anthropologic implications of tooth wear and occlusal patterns, he clarified his understanding of the neurophysiologic role of the canines (D'Amico, 1961). "The natural vertical and horizontal overlap relation of the upper canines is not strictly a mechanical block. Their function is more than a mechanical guidance of the mandible and mandibular teeth into centric occlusion. The innervation of the periodontal membrane functions in the same manner as the innervation of the tendons, ligaments, muscles, and inner ear. Shock contact of the upper canines by the opposing mandibular teeth during eccentric excursions causes transmission of periodontal proprioceptive impulses to the mesencephalic root of the fifth cranial nerve, which in turn alters the motor impulses transmitted to the musculature. This involuntary action lessens the tension of the musculature, thus reducing the magnitude of the forces being applied." Thus "restoring the abraded areas of the canines to their original dimensions so as to eliminate the possibility of developing horizontal vectors will not only be a great aid in periodontal therapy, but it will also prevent further fatigue of the entire periodontium." Again the observations were without controlled data.

D'Amico's proposed reflex inhibition of the masticatory muscles through canine contacts has been clinically applied in the employment of canine guidance for decreasing muscle activity (Ramfjord and Ash, 1971, 1981, Chasens, 1972, Kahn, 1977, Carranza, 1979). But only recently has experimental data been presented to support D'Amico's conclusions (Williamson and Lundquist, 1983).

D. Experimental Observations

Adams and Zander (1964) did some of the foundational work investigating the question of tooth contacts during mastication. By the use miniature radio transmitters to collect data They observed that tooth contacts occurred more frequently in the intercuspal position than in the lateral positions and they commented in general that "occlusion of the natural dentition is important for most phases of the practice of dentistry, yet it has a poor foundation in research." The effort to improve that foundation is characterized by the work of A.G. Hannam. He has done extensive work with electromyographic (EMG) techniques. Yet he has recently reiterated that a lack of understanding exists concerning "the precise association between EMG activity in the muscles of mastication, patterns of jaw movement during chewing, and dental occlusion" (Hannam, 1981). These comments can be attributed to the complex nature of the neuromuscular system and a limited application of scientific methods.

The muscles and neural processes make up a sensory-motor system that is involved in the initiation, programming and execution of motor functions (Morgenson, 1980). This system is complex. Not even the muscular component of the system is simple. The anatomy of the closing muscles (masseter, temporalis, and medial pterygoid) and opening muscles illustrates the complexity of the system. Several of the muscles are composed of multiple parts (heads) that have distinct origins and insertions. Contraction of these various parts can add a forward or backward movement as well as up or down movements. And since the temporomandibular joints are involved simultaneously each movement requires bilateral coordination of closers and openers (Luschei and Goldberg, 1981). This coordination and organization of muscular action patterns require the translation of thought and emotion into movements by the motor system of the brain (Henneman, 1974). Therefore the isolation of a particular component of the system from the entire system of man is inappropriate except to facilitate a discussion of what would otherwise be a "bewildering array of neural mechanisms" (Ramfjord and Ash, 1983). The following discussion is organized with this in mind. It is intended to relate to a specific reflex mechanism such as D'Amico proposed in the 1950's.

1. Methods of Study

Actual study of the effect of canine guidance upon the musculature has centered upon chewing patterns (Yaeger, 1978). These studies of the chewing cycle have employed various levels of technology ranging from cinematographic methods (Hildebrand, 1931) to recent incorporation of computer study of the muscle EMG activity (Hannam, 1977). Another major area of investigation has centered on the relationship of occlusion and the musculature in temporomandibular joint dysfunction (Yemm, 1976).

Schweitzer (1961) used still and motion picture photography to study the actual movements of mastication. Using mechanical devices to move dental casts while the patient chewed and devices to trace the paths of mandibular motion, he observed several subjects chewing. He suggested that the path of closure to the position of intercuspation for adults with malocclusion and healthy oral structures is reflex in nature and is attained without cuspal clashing. Thus what appears as cuspal guidance may be nothing more than involuntary neuromuscular coordination in closing. While such study can reveal chewing patterns, the study was not meant to address the specific investigation of any reflex effect the canine guidance has upon the musculature.

Moyers (1949) initiated the use of electromyography (EMG) in dentistry with his work in the relationship between muscle function and facial form and growth. The EMG is a recording of the summated muscle action potentials. It can be recorded with

surface electrodes or intramuscular needle electrodes. Surface electrodes collect data from a larger region of the muscle. Needle electrodes from more restricted regions of the muscle can better localize the EMG activity but are invasive. The recorded EMG activity is usually correlated with position or movement of the jaw or biting force to provide meaning (Dubner, Sessle, and Storey, 1978). Analysis of the data can be as straight forward as noting the beginning and ending of muscle activity or as complex as assessing levels of activity (Moller, 1966, Hannam, 1977). Quantification is often achieved by measuring the amplitude of the tracing. This amplitude is the height of the summated action potentials. The amplitude alone can be misleading since it does not consider the frequency of the tracing. In some instances frequency analysis is the method of evaluating the EMG (Kadefors, et. al., 1973).

Besides these technical matters of localizing and quantifying the activity there is a theoretical concern about the nature of the muscle processes being recorded. In 1973 Moyers showed the difference in volitional and reflex muscle activity with respect to command swallowing versus reflex swallowing. The reader is referred to Desmedt's three volume reference (1973) on neurophysiology which reviews these problems and the scope of EMG and human reflexes in neuromuscular disorders in detail.

Schaerer, Stallard, and Zander (1967) used EMG recordings

to study the interrelationship between tooth contacts and muscular activity of the chewing muscles. They altered the tooth contacts by adding balancing interferences in three subjects. They concluded: that the EMG response during mastication was the same for the different types of tooth contacts; that tooth contacts are a part of the reflex mechanisms controlling mandibular movements and muscular contraction; and that these masticatory mechanisms are influenced by pressure and touch sensitive receptors when tooth contact occurs, regardless of when and in what maxillomandibular relationship they take place. Again the study addresses the canine guidance and musculature interrelationship only in a peripheral manner and no clear conclusion is drawn concerning the effect of canine guidance upon the muscles of mastication.

2. Proprioceptive Inputs

One of D'Amico's reasons for recommending canine guidance was his belief that the canine teeth "are extremely sensitive organs" which transmit in a "greater degree than any other teeth the desirable periodontal proprioceptor impulses ... reducing muscular tension" (D'Amico, 1955). This belief had not been tested experimentally until recently (Williamson and Lundquist, 1983). The question of tooth proprioception has led to the study of mechanoreceptive inputs from teeth. Researchers have concluded that while periodontal ligament receptors inhibit jaw closers

through inhibition of the motor nucleus, the overall motor response results from a coordination of receptors from the periodontal ligament, extraoral and intraoral epithelial surfaces, tongue, TMJ, and jaw muscles (Yaeger, 1978, Crumm and Loiselle, 1972, Willis and DiCosimo, 1979).

The periodontal ligament (PDL) is generally ascribed to function in five main roles: (1) formative; (2) supportive; (3) sensory; (4) nutritional; and (5) protective (Sicher and Bhaskar, 1972). The sensory role involves receptors. Lewinsky and Stewart (1936, 1937) reviewed the evidence for nerves in the periodontal ligament and concluded that they may follow two routes in the PDL. One pathway is from the apical to the gingival margin and the other is through foramina in the alveolar process. They noted two specific sizes of nerve fibers, thick and thin, in the PDL. Later, Dependorf and Simpson (1966) reported that fine nerve processes end in the cementoblastic region. Kizior, et. al. (1968) also described two fiber sizes. He found large ovoid fibers in the apical third and small free endings throughout the ligament. Susi (1978) suggested that the large diameter fibers discerned proprioceptive, touch and pressure stimuli while the small fibers conducted nociceptive information. The type of fibers in the PDL has been summarized as pressoreceptors with connections ascending to consciousness, pressoreceptors without connections to consciousness and pain receptors (Allgood, 1973). Thus it is clear from histologic

studies that the PDL has innervation (Willis and DiCosimo, 1979).

The receptors in the PDL do seem to respond to pressure stimuli (Crumm and Loiselle, 1972). The proprioceptive function of the PDL is believed to be due to the sensation of pressure through mechanoreceptors (Lammie, et al, 1959, Heners, 1974, Brewer and Morrow, 1975, Susi, 1978,). Because of this function some authors recommend the retention of teeth as proprioceptive aids and suggest that extraction of all teeth results in a complete loss of tooth proprioception (Brill, et al, 1959, Crumm, et al, 1971, Loiselle, et al, 1972). The common teeth to be saved for such purposes are the canines. Crumm and Loiselle (1972) state that the literature supports those who call the canine the proprioceptive organ.

Studies in man have failed to settle the claim that the canines have such a unique reflex role. Manly, et. al. (1952) found the canine is actually less sensitive to axial loading than the incisors. Later, Bonaguro, et. al. (1969) found the maxillary canine to have the highest discriminatory ability of all human teeth at forces over 200 grams. While in a chewing study Butler and Zander (1968) showed EMG recordings from a subject with canine guidance that showed no reflex alteration of closure. Most recently the investigation of Williamson and Lundquist (1983) has provided some evidence that canine guidance decreases masticatory muscle EMG activity.

The experimental evidence to support a claim of special proprioceptive activities for the canine comes from work done mainly in cats. In an experiment applying blunt pressure as stimuli to the oral tissues, Corbin and Harrison (1940) found that the canine teeth are the most sensitive of all structures tested. They found both the mandibular and maxillary canines responded to pressure in any direction with a large burst of potentials from the caudal portion of the mesencephalic nucleus. Pressure on the homolateral teeth, especially the incisors, evoked a similar response but to a lesser degree.

The canine teeth have been observed to be innervated by a large number of neurons (Jerge, 1964). In a study of the sensory trigeminal nucleus complex of cats, Kruger and Michel (1962) observed that "the canines are more richly represented than any of the other teeth, presumably a reflection of richer innervation and a greater usefulness of this tooth as a tactile organ." That the cat canine has a larger number of innervating neurons than any other tooth of the cat has been found by others (Eisenman, et. al., 1963, and Kawamura and Nishiyama, 1966). In 1966 Kawamura and Nishiyama made a topographic map of the trigeminal nucleus of the cat. It also showed that the canines are the most densely innervated teeth and that sensory information from individual teeth went to specific sites in the nucleus.

The extrapolation of these cat findings to man does not necessarily settle the question about the human canine's neuromuscular role. To begin with, there are anatomic problems with such extrapolations. The cat mandible has no translatory ability, so the cat canine cannot provide canine guidance. Thus this data cannot be readily applied to primates or man (Dubner, Sessle, and Storey, 1978). To further place such an extrapolation into perspective the anatomy of the human dentition should also be considered. The cat dentition differs from the human in that the cat canine is without closely approximating adjacent teeth. In the intact human dentition the canine generally has interproximal contacts with adjacent teeth. This arrangement gives different mechanics of response to lateral forces. Besides interspecies differences there are differences intraspecies. Gher and Verino (1980) have noted that the surface area of a human canine root is about 270 square mm while that of a first molar root is about 430 square mm. Thus while the human canine might have a greater density of neurons per unit of area, it might have a similar total number of neurons per tooth as the much larger first molar. The decreased surface area coupled with an increased density of neurons might translate into equivalent sensory input for the two human teeth. Thus the specific question of what effect canine guidance has upon the muscles of mastication is difficult to answer.

3. Control Mechanisms

Proprioception provides peripheral inputs for motor response. The reflex arc is the morphological basis for automatic motor response to sensory stimuli. A simple two neuron arc is called monosynaptic. A more complex arc may involve multiple neurons and is called polysynaptic. In the whole organism, two major reflexes are the myotatic (stretch) and flexor (withdrawal) reflexes. The stretch reflex is monosynaptic. The flexor reflex is polysynaptic. Sherrington's principle of reciprocal inhibition involves a reduction in tension in one muscle group to accommodate the contraction of its opponent group (Sherrington, 1906). Regarding the jaw, two major reflexes are the jaw closing reflex and the jaw opening reflex (Willis and DiCosimo, 1979). Peripheral control of chewing or biting is not provided by only one class of sensory receptors. The muscle spindles have been noted to fire in proportion to muscle stretch but not in proportion to bite force. Muscle stretch results in activation and contraction of the stretched closure muscles. The mechanoreceptors of the periodontal ligament fire in proportion to the bite force. Appropriate central connections cause relaxation of the closure muscles and in some instances simultaneous contracture of the opening muscles (Larson, Smith, and Luschei, 1981). Yet these reflex actions are not constant in all situations. Lund and Olsson (1983) have

presented a forceful case that such reflexes are modulated by a central pattern generator during the course of centrally initiated jaw movement. It is apparent that central motor mechanisms can suppress potentially interfering reflexes to permit an intended movement.

a. Jaw Closing Reflex

The jaw jerk masseteric reflex is a monosynaptic jaw closing reflex believed to be mediated mainly by muscle spindle proprioceptors (Corbin and Harrison, 1940, Szentagothai, 1948, Lund and Olsson, 1983). It is initiated by lightly tapping the chin which stretches the closer muscles (Szentagothai, 1948). However, this reflex might be mediated by more than muscle spindle afferents since the tap may activate receptors in the periodontium, temporomandibular joint, periosteum, skin, or mucosa and may involve pathways via the mesencephalic nucleus (Ramfjord and Ash, 1983). Lammie, Perry and Crumm (1959) also suggested that it is triggered via proprioceptive inputs from the joint and surrounding muscles.

Preceding closer muscle contraction, a very brief decrease of EMG activity can often be observed in the masseter and temporalis muscles if the jaw jerk reflex is evoked during sustained clenching. This period is called the silent period (Hellsing and Klineberg, 1983). The jaw closing reflex evoked by

a chin tap has been a major model for studying this period of decreased EMG activity. This period has also been observed in response to tooth contact during chewing (Scharer, P., Stallard, R. and Zander, H.A. 1967). A similar phenomenon is noted when tapping a tooth. It is called the periodontal masseteric reflex (Goldberg, 1971). The mechanism of this reflex might involve the periodontal receptors and the muscle spindles of the jaw closing muscles (Goldberg, 1972).

b. Jaw Opening Reflex

The jaw opening reflex has two components: the excitation and contraction of jaw openers and the simultaneous relaxation of the jaw closers. It is more complicated and polysynaptic (Jerge, 1964). In experimental animals, noxious stimulation of oral receptor afferents has been shown to activate both components, reflexly opening the mouth and relaxing the closer muscles from both the rest position or while clenching (Hannam, Scott, and DeCou, 1977). In humans, there appears to be mainly the second component of the opening reflex, the inhibition of the jaw closing muscles rather than contraction of the openers (Yemm, 1972) thought to be usually active in adults. While the component of the digastric reflex that contracts the opener muscles is not thought to exist in adults (Matthews, 1975) it has been noted in the human fetus (Humphrey, 1966) and also reported after mechanical stimulation of subjects performing clenching and

jaw opening exercises (Yamada and Ash, 1982).

The location of the receptors for this reflex has been studied. One possible afferent source could be muscle spindles in the jaw openers. Some studies have found spindles in the lateral pterygoid (Gill, 1974) which has historically been felt to be a jaw-opener. Yet most studies have failed to find spindles in the jaw-opening muscles (Kubota and Mesegii, 1972, Dymtruk, 1974). Thus it is concluded that few if any muscle spindles are in the jaw-openers (Crumm and Loiselle, 1972). Gill's finding can be placed in perspective by recent EMG work with the lateral pterygoid. Using intramuscle electrodes, Mahan, et. al. (1983) have found EMG evidence that the heads of the lateral pterygoid function in a reciprocal fashion representing a closer and opener muscle in the one lateral pterygoid muscle. Thus the spindles found by Gill might be in a closer and not an opener.

The more accepted site of afferents is intraoral tissues. While in experimental animal models, stimulation of the pulp serves as the means of activating this reflex, Pfaffman (1939) found that removal of the pulpal tissue did not abolish the reflex response. The vitality or lack of such has been noted to have no effect on proprioception for the jaw opening reflex (Adlre, 1947), because the reflex can still be evoked after removal of the dental pulp by stimulation of other intraoral

receptors such as the mechanoreceptors in the PDL (Hannam and Matthews, 1969). Sessle and Schmitt (1972) demonstrated that the second component, inhibition of the jaw closing muscles, could be attributed to the mechanical stimulation of the receptors about the teeth. A previous study (Hannam, Matthews, and Yemm, 1970) had used local anesthetic blocks to support the muscle spindles as the main mechanism.

c. Summary

The role of periodontal ligament receptors in jaw reflexes seems to be involved in the inhibition of the jaw closing muscles. When the jaw opens the closing muscles are stretched and the jaw closing reflex is activated for closure. As occlusion occurs, PDL receptors are excited and inhibition of the closing muscles is triggered (Willis and DiCosimo, 1979). Jerge (1964) based on his extensive studies on oral reflexes has suggested that simple reciprocal innervation as seen in the spinal cord is not utilized in the jaw movements.

A further point for consideration concerning control of the masticatory muscles is that while the canines of cats seem to have an increased density of neuron units, this has not been shown to be the case in man. However, it has been shown that the root surface area of human canines is roughly 60% of the root surface area of the first molars (Gher and Verino, 1980).

Therefore any variation in the density of neurons should be considered in light of the observed variation in surface area of roots. It is possible that the total neuron population of the canine with a greater density of neurons might equal that of the first molar with a greater root surface area.

These reflexes are modulated by a central motor mechanism that can suppress reflexes in opposition to an intended movement (Lund and Olsson, 1983). Thus there are peripheral and central inputs. The form, strength, direction and duration of a stimulus can influence the reflex as can the phase of muscle activity and the position of the jaw (Sessle, 1981). There is an inhibitory effect on the jaw closing muscles associated with periodontal receptor stimulation and an excitatory effect from the neuromuscular control of mastication and jaw movements. For a more in depth review of these matters the reader is referred to Jerge (1964), Luschei and Goldberg (1981) and Lund and Olsson (1983).

4. A Recent Investigation

Using EMG monitoring and altering the occlusion, Williamson and Lundquist (1983) have recently examined masseter and anterior temporalis muscle activity. These investigators varied the patients' occlusal guidance to experimentally test D'Amico's conclusions. Their stated purpose was to determine the

effect of two occlusal schemes on the anterior temporalis and masseter muscles. Five subjects, all female, were used. Four subjects reported a history of dysfunction or pain associated with the temporomandibular joint. A maxillary occlusal splint with canine guidance provided anterior guidance. EMG activity was recorded by surface electrodes while the patients went through excursive movements with and without the splint in place. These excursive movements were made both to the right and left and then to the protrusive positions. The guidance pattern was altered by grinding off the anterior guidance to allow for posterior tooth contact in the eccentric movements. A further variation of the guidance was provided by the natural dentition when the subjects were tested without the splints. This would also have the added effect of altering the muscle lengths because of the changes in vertical dimension of occlusion. The details of specific tooth contacts on the splint guidance were not given. The sequence of recording was constant. The subjects all began with canine guidance without counterbalancing of guidance patterns.

The resultant EMG tracings were evaluated visually. The tracings selected to illustrate the study showed a decreased amplitude with excursive clenching. No numerical quantitative analysis of muscle activity was attempted, therefore a statistical comparison of the effects of canine or other guidance patterns was absent. The tracings were evaluated on a subject by

subject basis with no group comparison of performances. On one subject during left laterotrusive movement on the left canine and the splint there was "an immediate decrease in electromyographic activity of all muscles. The greatest reduction of activity was seen in the right temporal and masseter muscles." This continuous activity at a decreased amplitude was noted in the four subjects with previous problems associated with the temporomandibular joint. Without the splint and with the posterior teeth in contact "there was continuous involvement of all muscles during this movement." In a different subject the effect of removing the anterior guidance and testing in right laterotrusive movement with the splint in place was illustrated as a typical finding. "Minimal electromyographic activity continued when the anterior guidance discluded the posterior teeth. No decrease in EMG activity is observable after the anterior guidance was removed, except for the right temporal muscle."

Williamson and Lundquist concluded "that only when posterior disclusion is obtained by an appropriate anterior guidance can the elevating activity of the temporal and masseter muscles be reduced." Further, it is not the contact of the canines that decreases the activity of the elevator muscles, but the elimination of the posterior contacts.

This finding that canine guidance inhibits the anterior

temporalis and masseter muscles is very significant. Such a hypothesis provides a rationale for the employment of canine guidance for patients being treated for parafunctional habits or having occlusal reconstruction. However the above study has two major deficiencies: inadequate quantification of the observed EMG activity, and inadequate controls. The EMG activity was never expressed in a numerical manner so that statistical analysis could be done. The controls were poorly described in that little or no information was given concerning which teeth provided the occlusal contacts for guidances. Finally the presentation of trials was not counterbalanced leaving the possibility that factors like fatigue and learning might effect the results.

E. Statement of Problem

The literature review has been concerned with the genesis of occlusal theories for patient management. A specific concern was the origin of the premise that a component of anterior guidance, canine guidance, is beneficial. The literature was traced in a historical manner to illustrate the fact that this premise is not well founded upon experimental evidence. This present study does not address all of the benefits ascribed to canine guidance. It is limited in scope to D'Amico's premise that canine guidance results in "relaxation" of the muscles of mastication. It tests this premise in light of currently

practiced splint therapy. The discussion of the other benefits is intended to give the reader background information.

In a section titled "Experimental Observations" some of the controlled studies were reviewed. The need for good clinical trials and the problems of studying the complex neuromuscular system of the jaw were discussed. The basics of proprioceptive inputs from the teeth and the reflex control of the muscles of mastication were reviewed. The human applicability of the finding of increased neuron units about the canines of cats was considered. And finally the only experimental study to test D'Amico's premise was reviewed. The major problems with that study were inadequate quantification of the observations and inadequate controls.

This study will attempt to more accurately test the premise that canine guidance provides a relaxation of the muscles of mastication. The methodology will produce objective measurements, i.e., numerical data for statistical analysis. The EMG signal from the polygraph will be recorded as a tracing and integrated for a numerical measurement. The control condition will be improved, i.e., only one variable will be changed between the experimental and control conditions. The experimental guidance of canine guidance will be compared to only one other guidance pattern. The clinical antithesis of canine guidance, molar guidance (Ramfjord, 1984), will be used for a comparison

of effects. Both guidance patterns will be developed at the same vertical opening on a maxillary splint with the natural dentition not involved in the guidance. A within subject design will be used to control for variance among subjects, i.e., strength of musculature. Counterbalanced presentations of the two guidance patterns will be used to control for the effects of fatigue and learning.

F. Null Hypothesis

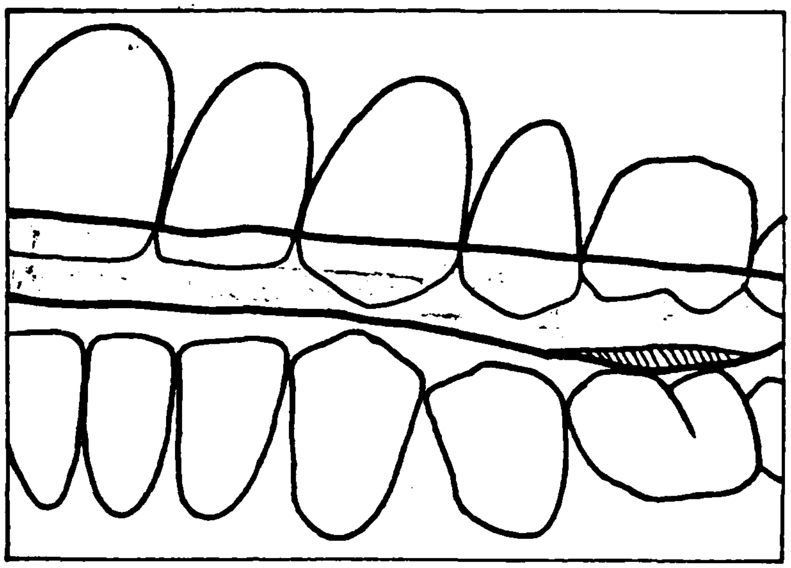
This study will test the hypothesis that there is no statistically significant difference in masticatory muscle electromyographic (EMG) activity while clenching during a lateral movement or in a lateral excursive position on a maxillary occlusal splint with canine guidance and first molar guidance alternated.

III. METHODS AND MATERIALS

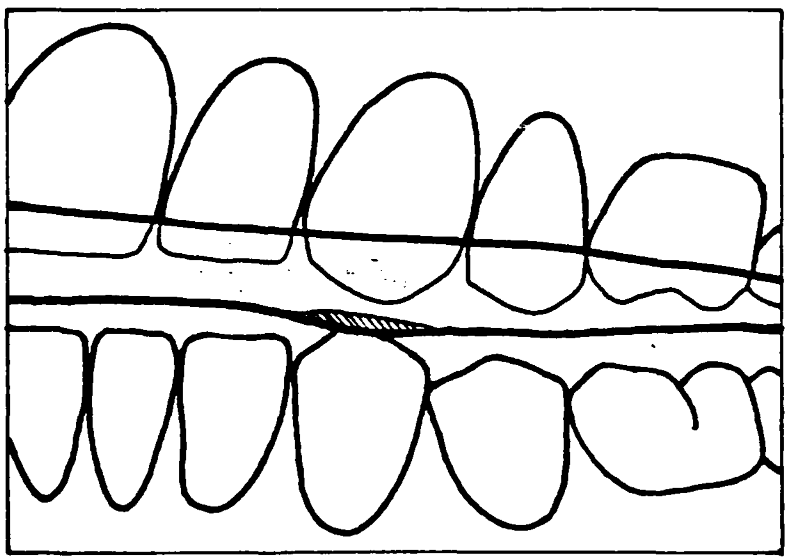
A. Overview

This study attempts to assess the effect that different occlusal guidances have on the electromyographic (EMG) activity of the muscles of mastication during clenching. The design calls for a comparison of EMG activity of the masseter and anterior temporalis muscles for both canine guidance and first molar guidance on occlusal splints (Figures #1 & #2). Ten subjects without a history of temporomandibular dysfunction and with noncontributory medical histories were monitored during clenching in centric occlusion and excursive position on each occlusal pattern. Three phases of clenching were actually recorded. The three phases of measurement were (1) clenching in centric occlusion with all teeth occluding, (2) clenching while moving into right excursive position with only the canine or first molar occluding, and (3) clenching in right excursive position with only the canine or first molar occluding (Figure #3). Four muscles per subject were monitored during these three clenching phases. Five series of executing these three phases of clenching were recorded for each subject for each of the two occlusal patterns. Each of the five series per subject consisted of a 15 second recording divided equally among the three phases of

Figure 1. Schematic representation of the lateral view of the splint guidance patterns. This view of maxillary splint illustrates the canine and first molar ramps. Occlusal contact was maintained on one tooth only.

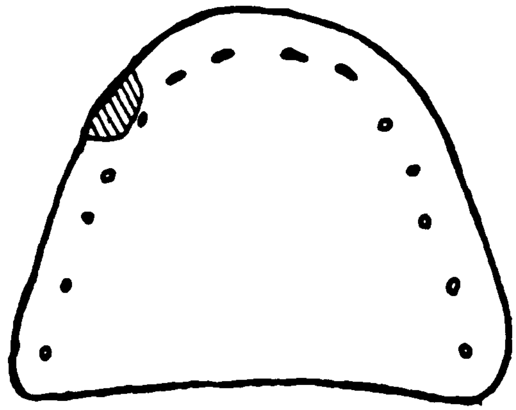


First Molar Guidance

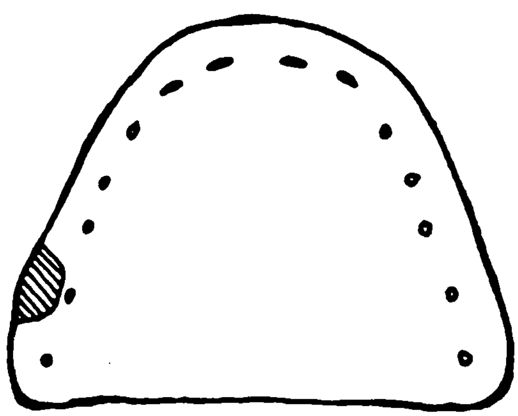


Canine Guidance

Figure 2. Schematic representation of the occlusal view of the maxillary splint. This view illustrates the canine and first molar ramps. Centric contact points for the mandibular teeth are not varied between the two guidance patterns.

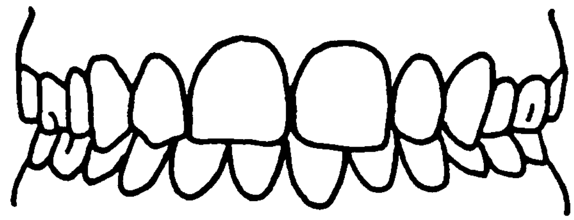


Canine Guidance

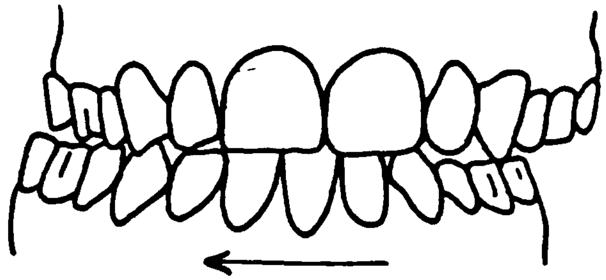


Molar Guidance

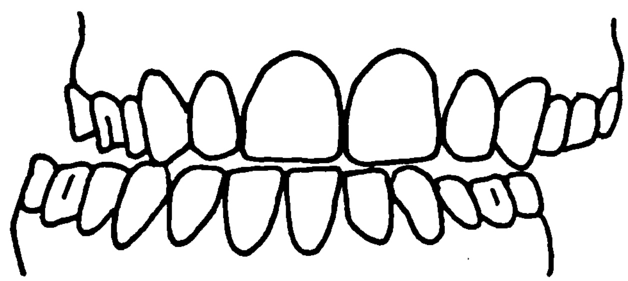
Figure 3. Facial view of the mandible positions for the three phases of clenching. The positions are centric occlusion clench, movement into right lateral position, and right lateral excursive clenching. The positions are illustrated without the splint in place.



Centric Occlusion Clenching

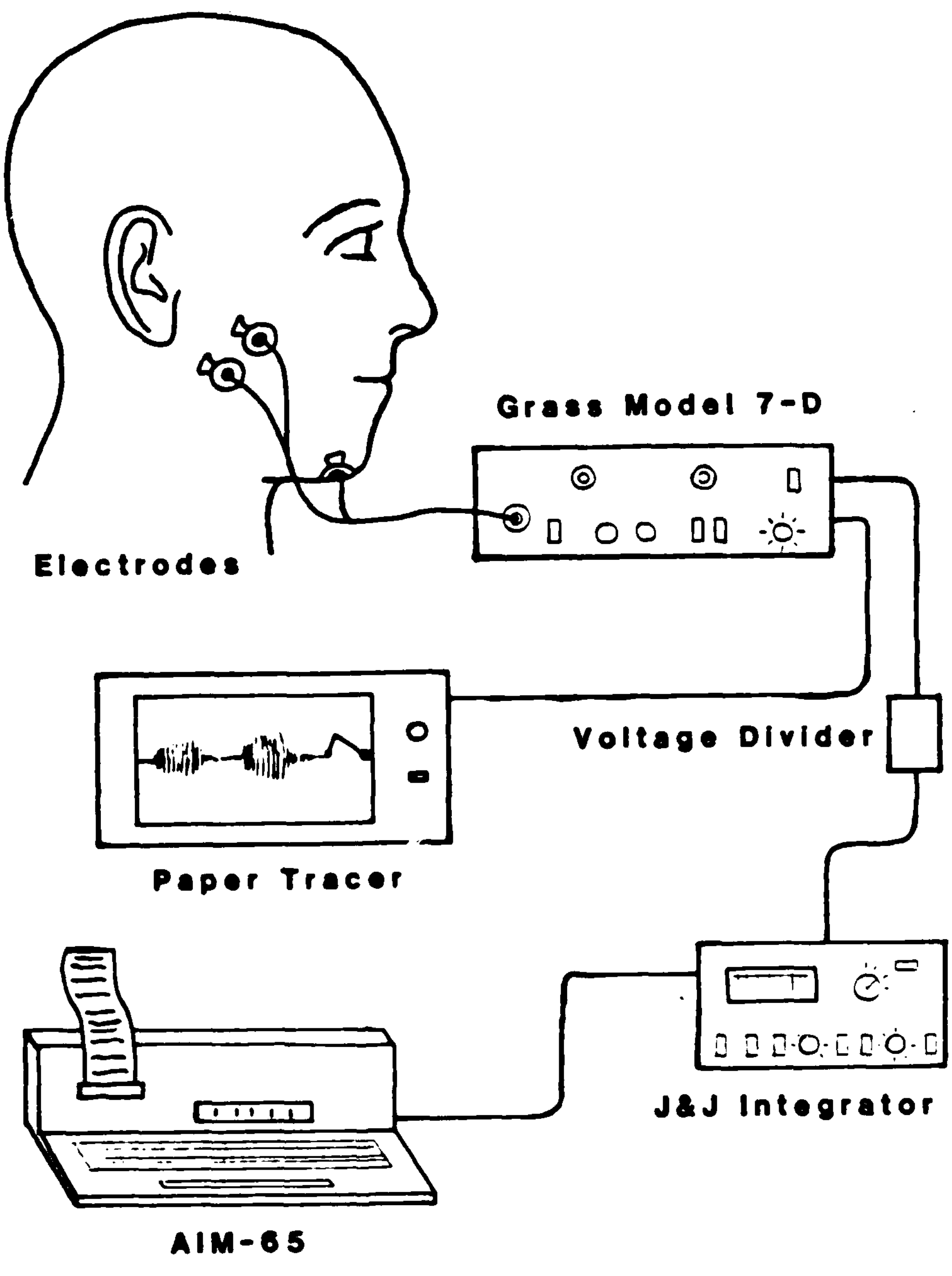


Right Excursive Movement



Right Lateral Clenching

Figure 4. Schematic illustration of the instrumentation for recording EMG activity. One of four channels is shown. Surface electrodes over the muscle send the signal to the Grass Polygraph. After amplification and filtering the signal is then recorded on the paper tracer. A second output from the preamplifier is sent to the J & J Integrator through a voltage divider. The results of the integration are stored and printed by the AIM 65 computer.


Grass Model 7-D
Electrodes
Voltage Divider
Paper Tracer
J&J Integrator
AIM-65

clenching. The EMG signals were recorded by a Grass Model 7D polygraph and integrated by two J & J Model M-53 EMG integrators (Figure #4). After preamplification the signal from the Grass 7-D preamplifier output (Figure #4) was reduced in level before entering the J & J integrators. These integrators measured the EMG activity as root mean square (RMS) values. An AIM 65 computer stored and printed the integrated scores. For each series, the three middle one- second samples from each phase were averaged to quantify the level of EMG activity. These averages (Tables A-1 to A-10 in appendix) are the raw data. With clenching in centric occlusion representing 100% effort, ratios of EMG activity comparing performance in the movement phase and excursive clenching phase with the centric clenching phase were calculated to determine percentages of EMG reduction. These ratios were statistically analyzed for difference between the two guidance patterns.

B. Study Population

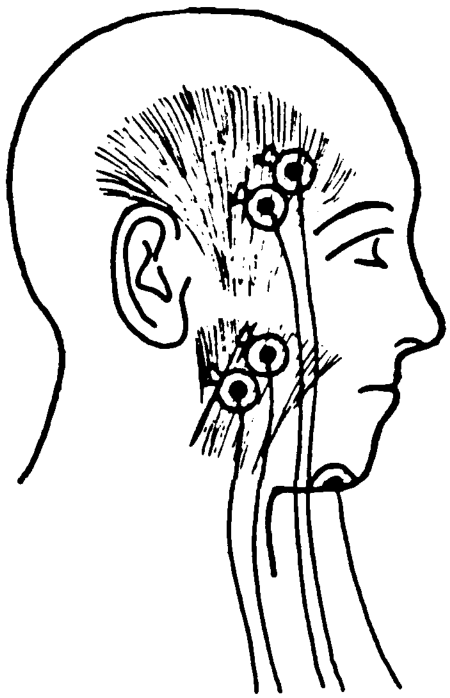
Ten volunteers from the students, faculty, and staff at the University of Texas Health Science Center San Antonio Dental School served as subjects. The average age was 26.7 years (range 23-32). Four subjects were male and six subjects were female. All were free of pain and dysfunction of the temporomandibular joint. Each had a full coverage maxillary splint (Figure #2).

These splints had been made as part of technique courses, were of similar design and construction (Ramfjord and Ash, 1971), and were well retained and stable during function. All subjects had a full complement of teeth with occlusion to the second molars.

C. Collection of Data

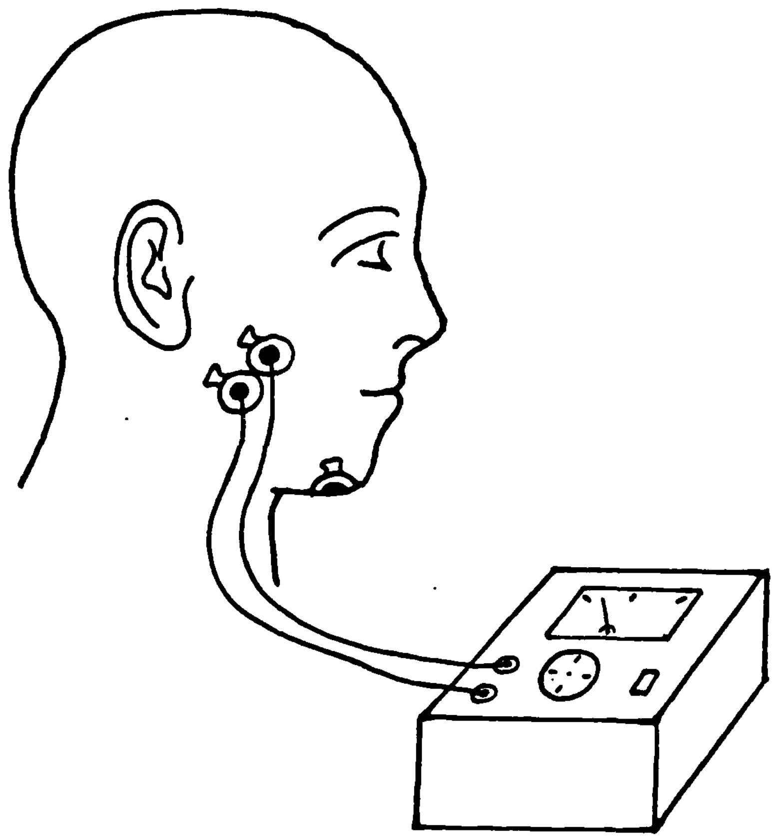
Bilateral EMG recordings of the masseter and anterior temporalis muscle activity were obtained by two-millimeter diameter silver-silver chloride EMG surface electrodes. Each muscle had two electrodes positioned two centimeters apart along its length (Figure #5). The electrodes were positioned over the bulk of the masseter muscles and over the anterior temporalis muscle as close to the hairline as possible. A five millimeter diameter silver-silver chloride surface electrode on the submental region served as a common ground (Figures #4 & 5). Skin preparation involved a thorough cleansing with alcohol wipes. To provide good electrical contact, Redux Cream by Hewlett Packard was applied and worked into the skin. The cream was worked into the skin with the wooden end of a cotton swab. Then the electrodes were attached by adhesive collars. To check contact integrity after electrode placement, each electrode was tested against the ground with a Grass Model EZM-1-E impedance meter (Figure #6). The level of acceptable impedance was <10 K ohms.

Figure 5. Illustration of the electrode positioning. A five millimeter diameter electrode is on the submental region. Twin two millimeter electrodes are placed two centimeters apart along the long axis of the muscle. The electrodes were placed over the greatest bulk of the masseter muscle. Over the temporalis the electrodes were placed as close to the hair line as possible.



Electrode Placement

Figure 6. Schematic illustration of the instrumentation for checking contact integrity. This check was done for each electrode after skin placement of the electrodes.

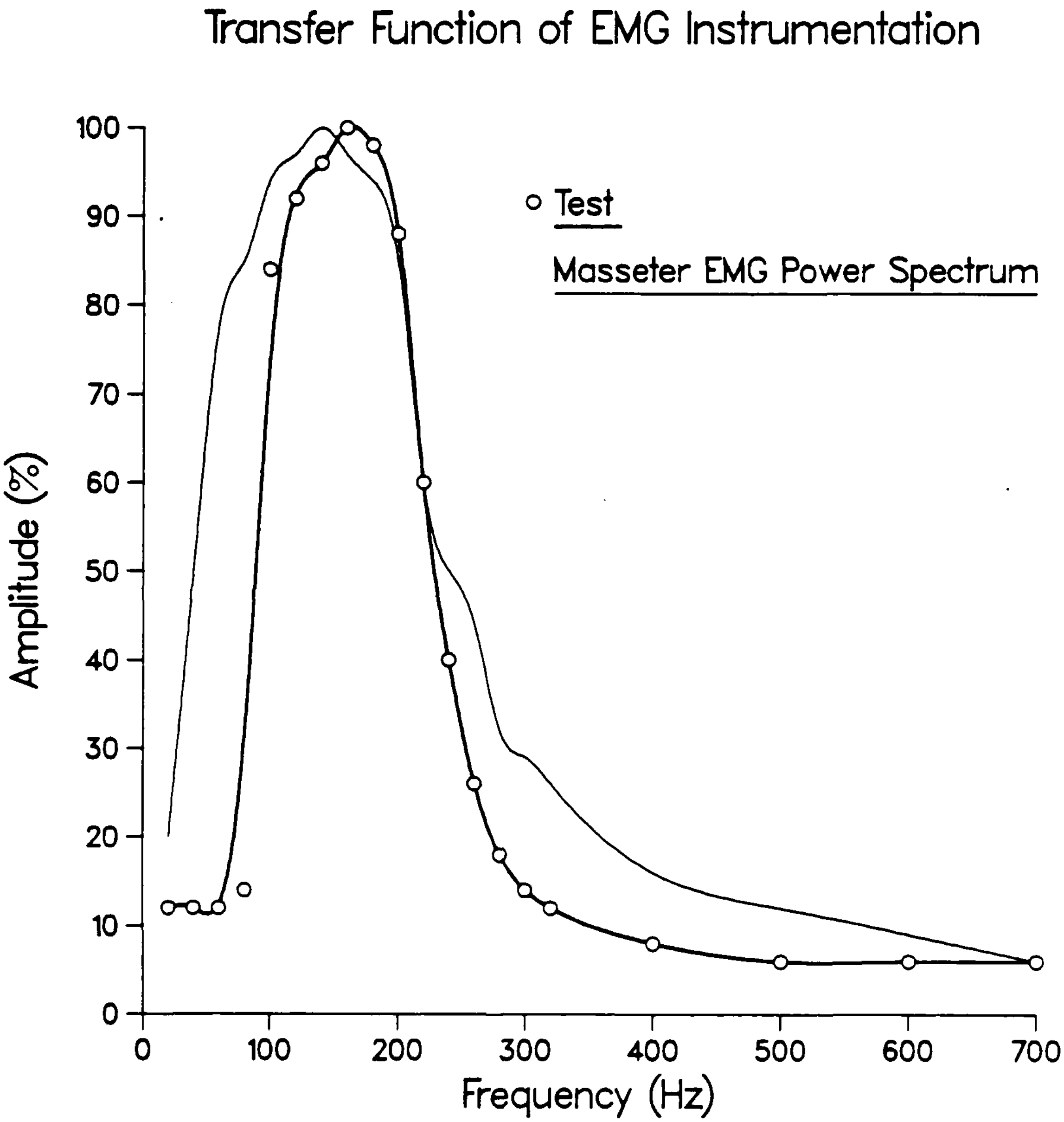


Impedance Check

Muscle EMG activity was recorded by a Grass Model 7D polygraph with wide band Grass model 7DAF pre-amplifiers (Figure #4). Figure 7 illustrates the bandpass recorded. The instrumentation recorded a similar frequency range as generated by the human masseter muscle. Before each session the instrument was calibrated with a 50 microvolt test signal. Calibration was done for each channel for each subject. For quantification, the signals from four preamplifiers were integrated by two J & J Model M-53 EMG integrators and stored in an AIM 65 computer. The same instruments were used for all recordings (Figure #4). A 100 microvolt root mean square sine wave test signal at 150 Hz sent through the instrumentation registered 40 units on the AIM. Therefore a correction factor of 2.5x is needed to convert the raw data into Root Mean Square (RMS) microvolt units. This test signal was monitored by a Fluke 8060A True RMS Multimeter.

During each series of clenching-movement-clenching, measurements were made for 15 one second samples. The commands given to the subjects were "clench", "move", and "clench" (Figure #8). These commands began the phases of clenching in centric occlusion, movement into right excursive while clenching, and clenching in excursive position. EMG readings were taken for five separate series for each occlusal guidance pattern. Each series involved (1) five seconds of clenching in intercuspal position, (2) five seconds of sliding from centric to right

Figure 7. Transfer function of the EMG instrumentation. The lighter line is the power spectrum of the masseter muscle according to Chu, Rugh, and Lemke, 1984. The circles identified as test are actual frequency response data recorded through the current experiment instrumentation. The bold line is a best fit regression curve drawn by a plotter using Tellagraf software.



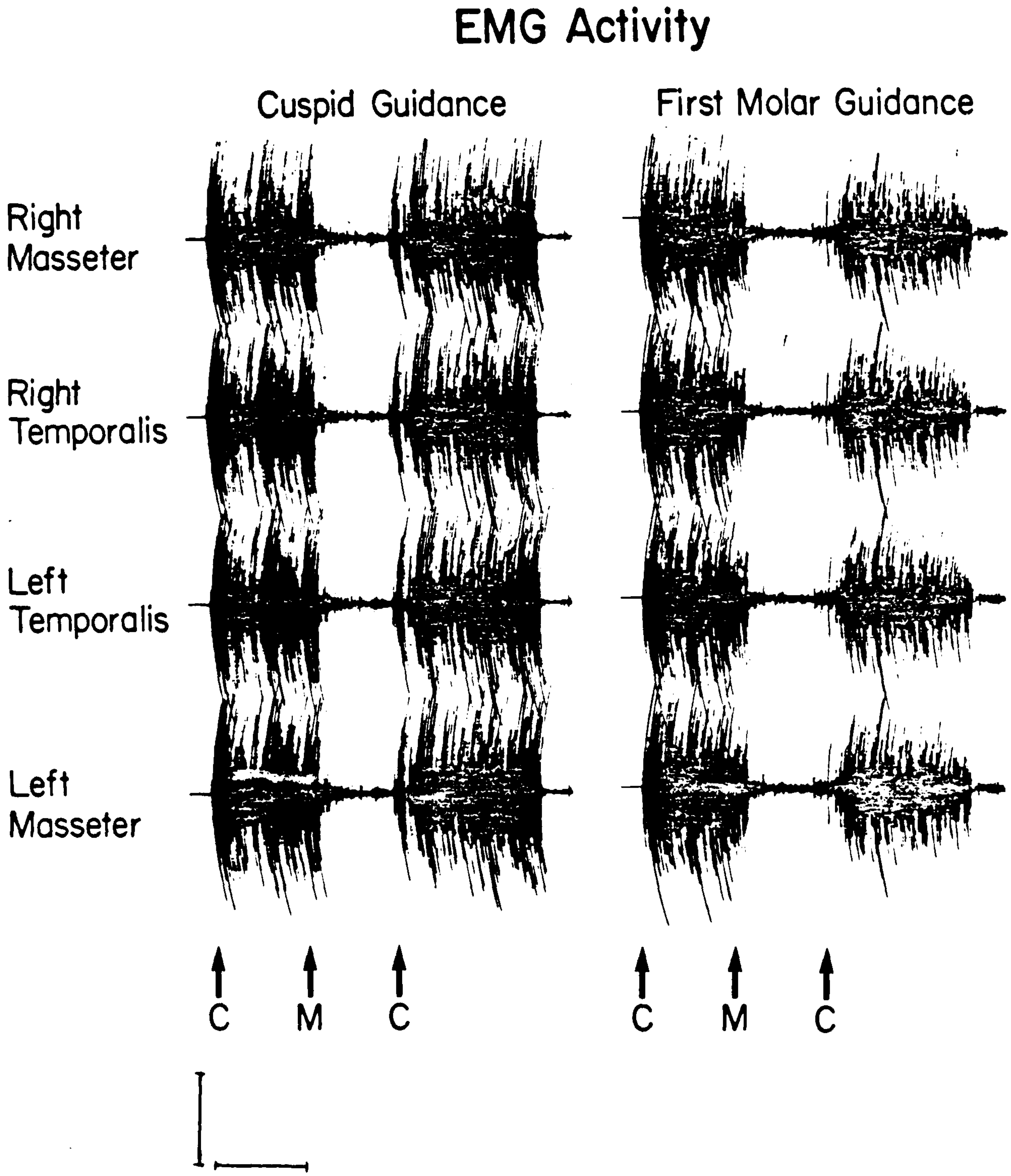
Transfer Function of EMG Instrumentation
Test
Masseter EMG Power Spectrum
Amplitude (%)
Frequency (Hz)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700

lateral excursive, and (3) five seconds of clenching in a canine to canine lateral excursive position with the splint constantly controlling the occlusal guidance. The commands were given at 0, 5 and 10 seconds for each series. Several practice runs were done to ensure that the patient understood the commands. A marker was placed on the EMG tracings to record the timing of the commands.

A within subject design was used to provide controls. To control for order effects the presentation guidance patterns were counterbalanced, i.e., canine guidance was alternated with first molar guidance as the first occlusal pattern to be tested. The splint was subsequently adjusted to provide either first molar guidance or canine guidance respectively. The canine guidance ramp was of sufficient height to provide 1-2 mm clearance in the molar region. The molar guidance ramp provided for the same extent of opening in the lateral positions. The position for centric occlusion clenching was not altered when the canine and first molar guidances were adjusted. The stability of the centric occlusion contact was maintained to provide a similar base for the 100% effort reference EMG activity against which the effects of canine and first molar guidance were compared.

Four channels of the Grass polygraph provided graphic representation of the muscle EMG activity (Figure #8). A fifth

Figure 8. Photocopy of an EMG tracing. All four muscles are recorded on four channels of the Grass Polygraph. The letters C-M-C indicate the timing of the commands given to the patient: "clench-move-clench". The vertical calibration bar represents 100 microvolts and the horizontal timing bar represents 5 seconds.

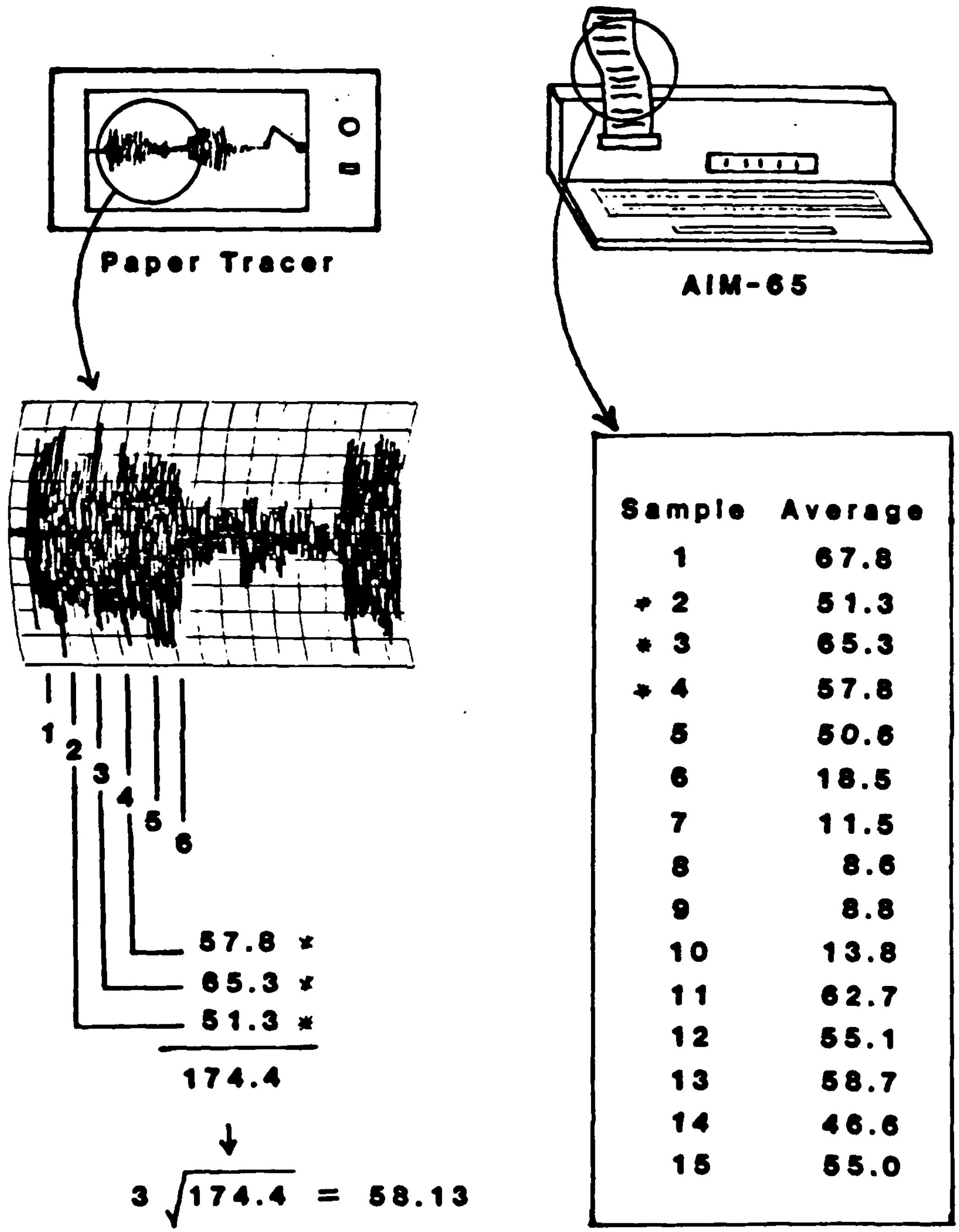

EMG Activity
Cuspid Guidance
First Molar Guidance
Right Masseter
Right Temporalis
Left Temporalis
Left Masseter
C
M
C
C
M
C

channel of the polygraph recorded the timing of the commands to begin clenching, movement, and clenching. The AIM 65 stored and recorded the RMS values for the 15 one-second samples per guidance pattern per subject. These raw EMG data were continuously monitored during the recording periods to insure that the subjects were following instructions. The narrow 60 Hz filter on the Grass was "in" to provide 60 Hz artifact suppression. The chart recordings were also examined visually for 60 Hz noise artifact.

D. Analysis of Data

For quantification the EMG activity was integrated by the J & J integrators and stored and printed by the Aim 65 computer. Each series had fifteen one-second samples throughout the three phases of clenching. These samples were distributed as five one-second samples during centric clenching, five one-second samples during movement, and five one-second samples during excursive clenching. The beginning of each of the three phases was indicated by the command timing marks on the fifth channel of the EMG tracing. The first and fifth samples were discarded to allow for transition from clenching to movement to clenching. The remaining middle three one-second samples were averaged (Figure #9). These averages for each of the five series were recorded as

Figure 9. Illustration of the two data processing and display methods. The paper trace recorded a graphic representation of the EMG activity while the AIM 65 recorded the numerical integrations of the EMG activity. Graduated paper provided a means to correlate the two recordings as illustrated by the 2, 3, and 4 second samples. The three one-second samples were averaged to arrive at the raw EMG score for the given five second phase.



Paper Tracer
AIM-65
1
2
3
4
5
6
57.8 *
65.3 *
51.3 *
174.4
3 √174.4 = 58.13
Sample Average
1 67.8
* 2 51.3
* 3 65.3
* 4 57.8
5 50.6
6 18.5
7 11.5
8 8.6
9 8.8
10 13.8
11 62.7
12 55.1
13 58.7
14 46.6
15 55.0

the mean raw EMG scores (Tables A-1 to A-10). A total of five consecutive series were recorded for each occlusal pattern.

Using these mean integrated data, intrasubject percentages of reduction of EMG activity were calculated for the two guidance patterns. With clenching in centric occlusion representing 100% effort, reductions in EMG activity were calculated for clenching during the movement and excursive phases. These percentages were used for the analysis to compare the effects of the two guidance patterns. The percentage reductions were calculated as ratios by the following formulas:

C = EMG score during clenching in centric occlusion

M = EMG score during movement to excursive occlusion

E = EMG score during clenching in excursive occlusion

c indicates canine guidance

m indicates first molar guidance

#1 ---- [(Cc - Mc)/Cc][100] = EMG percent reduction during movement on canine guidance

#2 ---- [(Cm - Mm)/Cm][100] = EMG percent reduction during movement on molar guidance

#3 ---- [(Cc - Ec)/Cc][100] = EMG percent reduction during excursive clenching with canine guidance

#4 ---- [(Cm - Em)/Cm][100] = EMG percent reduction during excursive clenching with molar guidance

Ratios #1 and #2 were used to determine the percentage reduction in EMG activity during the movement phase. Ratios #3 and #4 were used to determine the percentage reductions of EMG activity during the clenching in excursive position phase. A comparison of ratios #1 and #2 indicates the relative effects of canine guidance and first molar guidance upon the EMG activity during the movement phase. A comparison of ratios #3 and #4 indicates the relative effect of canine guidance and first molar guidance during excursive clenching. In both cases, if the effects of canine guidance and first molar guidance are similar there will be no statistically significant difference between the ratios.

The effect of guidance pattern on the EMG activity was evaluated using the Student's t test. Ratios of EMG performance on canine guidance and first molar guidance (Tables 1, 2a, 2b) were compared for the muscle groups. An analysis of variance was also done to compare the relative changes in EMG activity for individual muscle pairings using the same guidance pattern (Table 3). These analyses were done on a DEC VAX-11 computer using Department of Biomathematics, University of California software. A 0.05 level of significance was used.

IV. RESULTS

Jaw muscle activity was reduced during both lateral movement and excursive position clenching. This was found true on both canine guidance and first molar guidance patterns. The reductions in EMG activity for canine and first molar guidance splints were not significantly different.

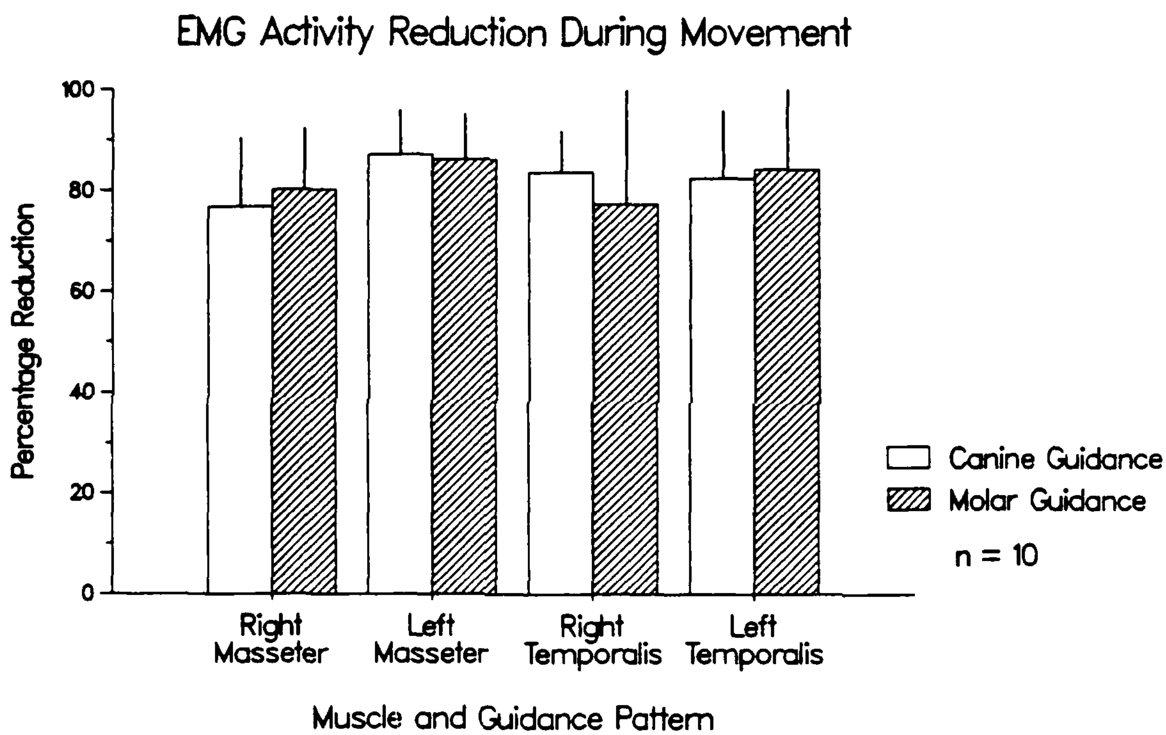
Average reductions of grand mean EMG activity (Table 1) for the movement phase were 81.8 $\pm$14.0% on splints with canine guidance and 81.6 $\pm$19.2% on splints with first molar guidance. Average reductions of grand mean EMG activity in the excursive clenching phase were 44.7 $\pm$26.7% on splints with canine guidance and 42.6 $\pm$29.7% on splints with first molar guidance. There was no statistically significant difference in these reductions for the same clenching position on either guidance pattern.

Besides comparing grand mean EMG scores, individual muscle performances were compared using a t test. It revealed no statistically significant differences in the reduction of muscle activity by specific groups (Tables 2a & 2b for ipsilateral and contralateral muscles respectively) on either of the two occlusal patterns.

To check individual muscle performance variation during any one guidance pattern, an analysis of variance for differences was used. This analysis revealed that among the four muscles monitored, the reduction of EMG activity for the same occlusal guidance pattern varied only in one comparison (Table 3). During a right excursive movement on canine guidance the left masseter showed a greater reduction in EMG activity than the right masseter.

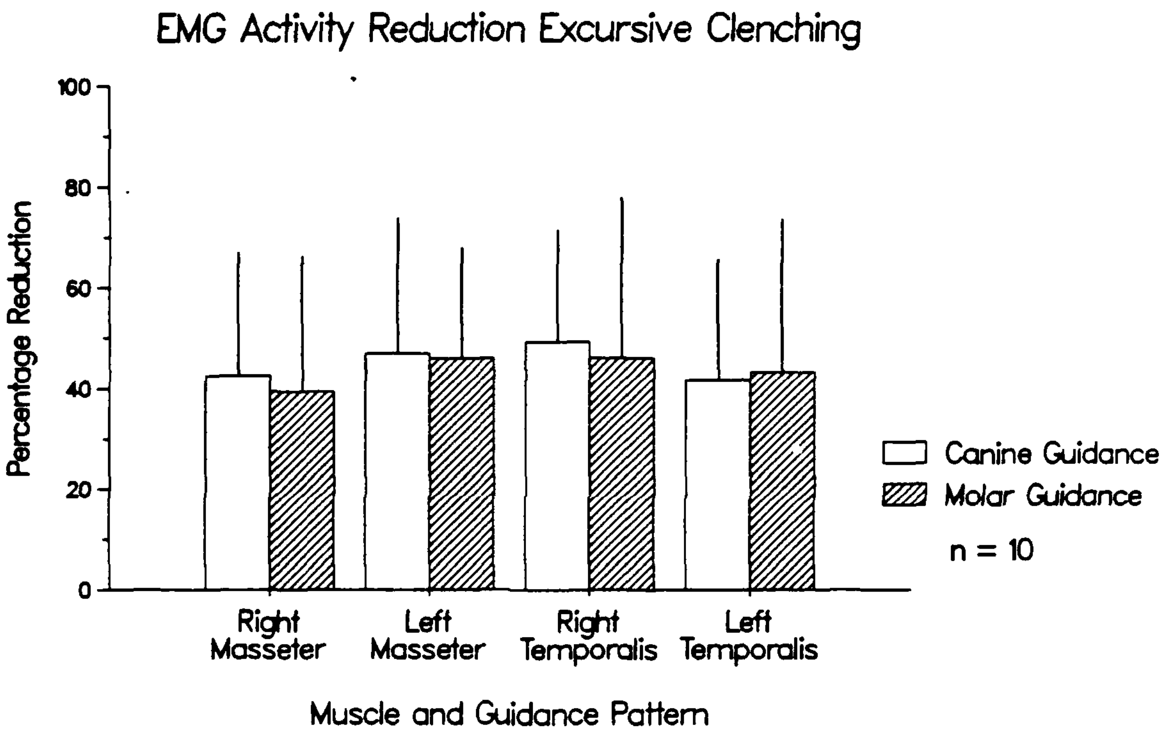
Each of the five series of recordings per subject were treated as independent trial. This was done because the recordings were made at distinct times during a recording session. Thus there were the possibilities of learning and fatigue during the independent measurements. This handling resulted in the n's of Tables #1, #2a, #2b, and #3 (i.e. n = 50 = 5 trials X 10 subjects). Because it could be argued that each patient was one trial, the data was restructured such that n=10. Graphs #1 and #2 display the results of this treatment. An analysis of repeated measurements verified that there was no statistically significant difference in the percentage reductions of EMG activity between the two guidance patterns.

Figure 10. Graphic representation of the EMG activity reductions during the movement phases of recording.



EMG Activity Reduction During Movement
Percentage Reduction
100
80
60
40
20
0
Right Masseter
Left Masseter
Right Temporalis
Left Temporalis
Muscle and Guidance Pattern
Canine Guidance
Molar Guidance
n = 10

Figure 11. Graphic representation of the EMG activity reductions during the lateral excursive clenching phase.



EMG Activity Reduction Excursive Clenching
100
80
60
40
20
0
Percentage Reduction
Right Masseter
Left Masseter
Right Temporalis
Left Temporalis
Muscle and Guidance Pattern
Canine Guidance
Molar Guidance
n = 10

TABLE 1

PERCENTAGE REDUCTION
of MEAN EMG ACTIVITY
from CENTRIC CLENCHING

Phase	Guidance	EMG Reduction
MOVEMENT CLENCHING	Canine	81.8 ±14.0%
	Molar	81.6 ±19.2%
	t	1.19
	p value	0.23
EXCURSIVE CLENCHING	Canine	44.7 ±26.7%
	Molar	42.6 ±29.7%
	t	0.74
	p value	0.46

sample size: n = 200

TABLE 2a

COMPARISON by GUIDANCE PATTERNS
of MEAN PERCENT REDUCTION of EMG ACTIVITY
for INDIVIDUAL IPSILATERAL MUSCLES

Phase	Guidance Pattern	Ipsilateral Masseter	Ipsilateral Temporalis
MOVEMENT CLENCHING	Canine	76.6 ±15.4%	82.1 ±13.6%
	Molar	80.2 ±13.4%	76.9 ±26.3%
	t	1.24	1.24
	p value	0.22	0.22
EXCURSIVE CLENCHING	Canine	41.7 ±25.9%	49.2 ±24.3%
	Molar	38.7 ±29.0%	45.6 ±31.8%
	t	0.55	0.81
	p value	0.58	0.42

* t test results significant at $p < 0.05$.   sample size n = 50

TABLE 2b

COMPARISON by GUIDANCE PATTERNS
of MEAN PERCENT REDUCTION of EMG ACTIVITY
for INDIVIDUAL CONTRALATERAL MUSCLES

Phase	Guidance Pattern	Contralateral Masseter	Contralateral Temporalis
MOVEMENT CLENCHING	Canine	86.8 ±10.8%	81.8 ±14.2%
	Molar	85.4 ±17.4%	83.8 ±16.9%
	t	0.48	0.64
	p value	0.62	0.52
EXCURSIVE CLENCHING	Canine	46.2 ±28.0%	41.6 ±28.4%
	Molar	44.3 ±24.9%	41.7 ±32.8%
	t	0.38	0.02
	p value	0.72	0.99

* t test results significant at $p < 0.05$.   sample size n = 50

TABLE 3

COMPARISON by MUSCLE PAIRS
of MEAN PERCENTAGE REDUCTIONS of EMG ACTIVITY
MEASURED on the SAME GUIDANCE PATTERN
for INDIVIDUAL MUSCLES

MUSCLE	CANINE GUIDANCE		MOLAR GUIDANCE	
	movement	excursive	movement	excursive
right masseter	76.6%	41.7%	80.2%	38.7%
right temporalis	82.1%	49.2%	76.9%	45.6%
p value	0.06	0.16	0.39	0.25
right masseter	76.6%	41.7%	80.2%	38.7%
left temporalis	81.8%	41.6%	83.8%	41.7%
p value	0.08	0.98	0.33	0.61
right masseter	76.6%	41.7%	80.2%	38.7%
left masseter	86.8%	46.2%	85.4%	44.3%
p value	** 0.0002	0.40	0.17	0.34
right temporalis	82.1%	49.2%	76.9%	45.6%
left temporalis	81.8%	41.6%	83.8%	41.7%
p value	0.93	0.16	0.07	0.51
right temporalis	82.1%	49.2%	76.9%	45.6%
left masseter	86.8%	46.2%	85.4%	44.3%
p value	0.05	0.58	0.03	0.84
left temporalis	81.8%	41.6%	83.8%	41.7%
left masseter	86.8%	46.2%	85.4%	44.3%
p value	0.05	0.39	0.69	0.66

sample size n = 50

The value given for the Boferroni test is the simultaneous significant p value of comparisons of all pairs of means.

* $p < 0.008$ is significant at the 0.05 level
** $p < 0.002$ is significant at the 0.01 level

V. DISCUSSION

In this study the electromyographic (EMG) activity of the masseter and anterior temporalis muscles was reduced with both canine guidance and first m^lar guidance during lateral excursive movement and excursive position clenching. Canine guidance was found to be no more effective than first molar guidance in producing this reduction. This finding does not support the work of Williamson and Lundquist (1983) who have concluded that only with canine guidance can EMG activity of the masseter and anterior temporalis muscles be reduced. To explain this difference in findings it is helpful to consider some of the similarities and differences between the two studies. After contrasting these two studies, some neurophysiologic explanations and clinical limitations of the present study will be discussed.

Despite what might be viewed as contrary findings, the two studies have some points of similarity. Like the Williamson and Lundquist work, this present study used a within subject design. However, the numerical data were converted to percent reductions of EMG activity for each phase of clenching on each guidance pattern. The raw data in the appendix (tables A-1 thru A-10) illustrate that not all patients achieved equivalent levels of activity. This interpatient variability can be theoretically accounted for by intrinsic and extrinsic factors.

Intrinsic variations such as subject size or biting force capabilities were controlled for by the within subject design. In the present study each patient generated the greatest EMG activity while clenching in centric occlusion. Hosman and Naeije (1979) looked at the relationship between the normalized integrated EMG activities of the human masseter muscle and the clenching force. They found that the relationship was linear up to approximately 80% of the maximal clenching force. Their conclusion was that it is possible to obtain standardized EMG recordings from the masseter muscle in humans by normalizing the integrated EMG recordings at maximal clenching. Therefore in this study the EMG activity level recorded during centric clenching was defined as a 100% effort for the given patient for the given trial. Any observed reductions were calculated from this reference level which was automatically adjusted for each trial during the DEC VAX 11 computer analysis of the data.

Extrinsic variation may be due to interelectrode distances, electrode type and exact placement over the relatively small masticatory muscles (Nouri, Rothwell, and Duxbury, 1976, Hosman and Naeije, 1979, Panchery and Winnberg, 1983). Such factors were controlled in both studies in that all recordings for each subject were done with one electrode placement during the same session. The same electrodes and recording apparatus

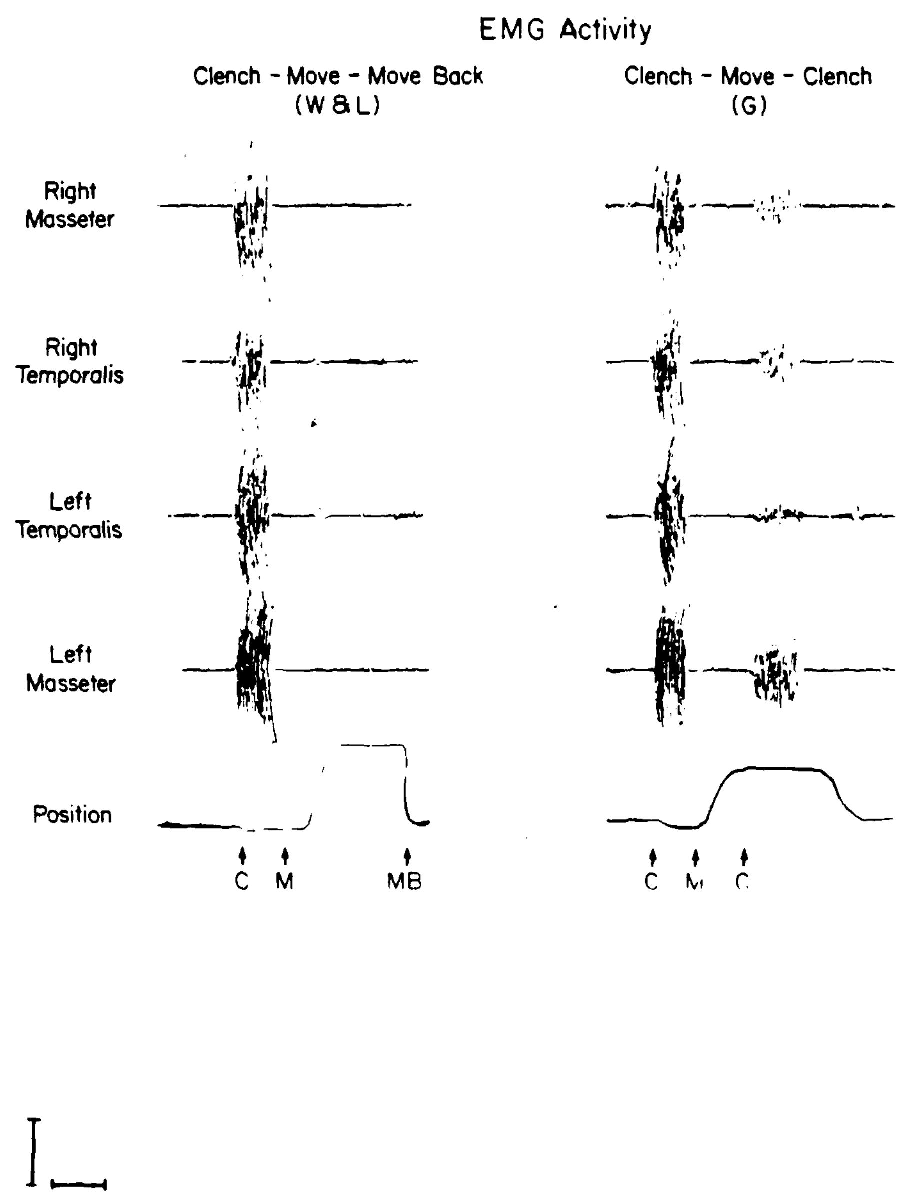
were used in all the subjects. Thus the intrinsic and extrinsic variables of monitoring the EMG were controlled as well as possible.

The calculated percentage reductions were subjected to statistical analysis to test for significant differences between the two guidance patterns. On the advice of two independent statistical consultants and basic texts on statistics, it was decided to use each series of recordings as independent trials. Thus each subject provided five trials for each guidance pattern giving the n values noted in tables 1, 2a, 2b, and 3. This decision might be questioned by some who would assign only one trial per subject per guidance pattern. This controversy is illustrated by periodontal studies where the investigators increase their n's by taking repeated measures at the same site (Fidler, 1984). It was felt that each series of measures in this study were separate trials because they were all distinct in time. However, because of this controversy the data was restructured so that each patient was a single trial (n=10) and the percentage reductions in EMG activity recalculated. These percentages are graphically represented in Figures #10 and #11 in the Results section. An analysis of repeated measures done on this data set showed there was still no statistically significant difference in the performances on the two guidance patterns.

The reduction in jaw closing muscle EMG activity was observed with lateral movement with both canine and first molar guidance. With both guidance patterns the magnitude of the decrease was similar. This observed reduction during the movement phase may be a prerequisite allowing lateral jaw movement which results mainly from excitation of the lateral pterygoids. The magnitude of canine guidance excursive movement EMG activity displayed in the Williamson and Lundquist article is visually similar to the magnitude observed in this study during the movement phases for either guidance patterns. Considering the similarity in these reductions it might be possible that the subjects observed by Williamson and Lundquist persisted to move throughout the observation periods. Unfortunately, neither study objectively documented and quantified the rates of movement for the excursive movement and clenching. As an addendum to this study one subject was monitored while a kinesiograph recorded the mandibular movement. While movement was present the EMG activity stayed depressed as in Williamson and Lundquist's study (Figure #12). When the subject stopped in an excursive position and purposefully clenched the EMG activity was not as dramatically reduced. Instead of the approximate 80% reduction in EMG activity observed during lateral movement the reductions were of the magnitude of 40% during purposeful excursive clenching.

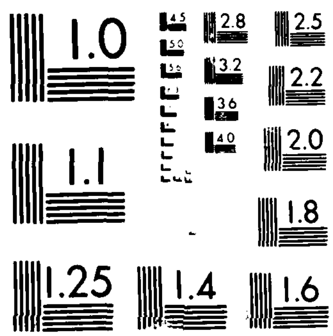
Such varied results illustrated in Figure #12 can be

Figure 12. Photo copy of EMG tracings done with different commands. The tracings on the left were done while the subject was commanded to clench-move-moveback. Note that the level of EMG activity stays greatly reduced. The tracings on the right were done while the subject was commanded to clench-move-clench. Note that the position indicator recorded that the patients were in a lateral excursive position and the EMG activity increased when the patient consciously clenched in the excursive position. The vertical calibration bar represents 100 microvolts and the horizontal timing bar represents 5 seconds.



EMG Activity
Clench - Move - Move Back
(W & L)
Clench - Move - Clench
(G)
Right Masseter
Right Temporalis
Left Temporalis
Left Masseter
Position
C
M
MB
C
M
C

AD-A171 967 THE EFFECT OF TWO MAXILLARY SPLINT OCCLUSAL GUIDANCE 2/2
PATTERNS ON THE ELEC..(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH G S GRAHAM MAY 86
UNCLASSIFIED AFIT/CI/NR-86-163T F/G 6/16 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

explained as above by the different methods employed for the experiments. Indeed, the studies differ greatly with respect to methodology. Two differences in methods which warrant discussion include: (1) the means of quantification of observations; (2) and the controls for the experiments. This first difference in methodology concerns the means of quantification of the EMG activity. As was noted earlier, this study used integration of the EMG activity to obtain numerical values. These values provided the data for statistical analysis to determine if the different guidance patterns provided significantly different masticatory muscle EMG activity levels. In the Williamson and Lundquist study the EMG activity was evaluated only by visual assessment of the tracings. However, visual assessment of the tracings in the present study did not always give a clear indication of the magnitude of reduction of EMG activity. In some instances it appeared that the activity was reduced more by first molar guidance than canine guidance. Figure #8 in the Results sections serves as illustration of such a case.

In contrast to the present study, the Williamson and Lundquist study showed graphic differences in EMG activity but the guidance patterns they contrasted present problems that lead to the second major difference in methodology between the studies. This second difference concerns the amount of detail

and variety of control guidance patterns.

In the previous study there was variation in how many teeth occluded, the movement patterns tested, and the vertical dimension of occlusion for the different guidance patterns. The decreased EMG activity observed on the two occlusal patterns may be influenced more by the number of teeth contacting than which tooth is contacting. Williams and Lundquist contrasted EMG activity for movement on a canine guidance splint with the natural dentition. Jerge (1963, 1965) has reported that the receptors in the PDL are directionally sensitive and that when one neuron innervates the receptors of several teeth, the activation is more effective when pressure is applied from a common direction. Comparison of guidance patterns with and without a splint would alter this activation by altering the independent role of each tooth. The amount of displacement of the teeth required for excitation of the mechanoreceptors is as little as 2-3 microns, with 10 microns resulting in a remarkable nerve excitation (Yamada, 1967). Thus very little displacement is necessary to generate PDL nerve excitation. In this manner the increased number of teeth occluding during excursive movements guided by the natural dentition might have had an important effect upon the EMG activity in the previous study. In contrast to the Williamson and Lundquist study, the number of teeth involved in this present study was kept at a constant of one during any excursive movement or clenching.

Besides varying the number of teeth involved in the occlusal guidance of the jaw movements, Williamson and Lundquist tested a variety of movements. These included protrusive and right and left lateral excursive movements. The pattern of movement tested in the present study was a simple lateral translation to the right. This pattern was chosen to increase control. With increasing complexity of movement patterns come increasing difficulties in establishing uniform and controlled occlusal guidance patterns. The more complex movement patterns would also result in a greater variety of force vectors upon the teeth. Because the PDL mechanoreceptors respond best to a force delivered in a single direction, (Wagers and Smith, 1960) the resulting effect on the masticatory muscle EMG activity could be dependent on the net force vectors involved. The various directions of mandibular movement would alter such vectors. Therefore differing results might be obtained in the two experimental conditions.

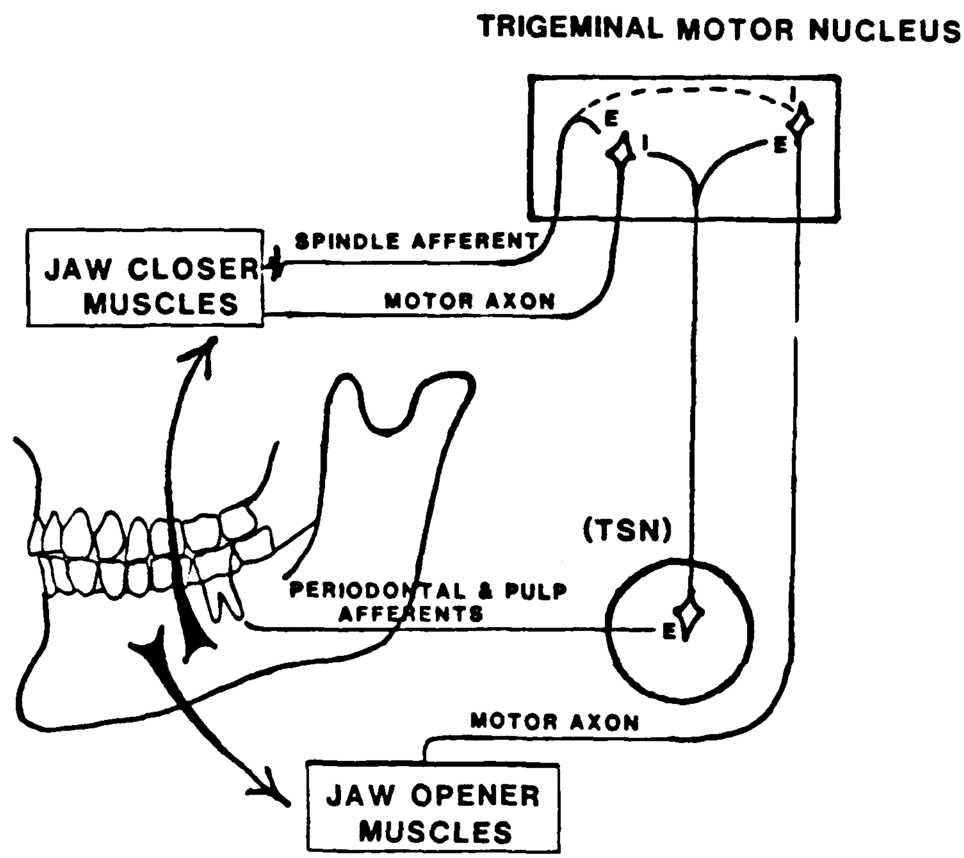
A final difference in control is the variation of the vertical dimension of occlusion. The Williamson and Lundquist study contrasted canine guidance on a splint with natural dentition guidance without a splint. This would alter the vertical dimension of occlusion and the length of the closing muscles. The simple act of placing a splint stretches muscle

spindles in the jaw closers and affects the temporomandibular joint afferents. This may result in an effect on the musculature. Upon placement of a similar maxillary occlusal splint, Kovaleski and DeBoever (1975) noted an immediate decrease in the resting EMG activity in 6 of 11 TMJ patients. In non-patients, Manns, Miralles, and Palazzi (1979) noted immediate increase in isometric contraction EMG activity when the vertical dimension was altered. The present study did not alter the vertical dimension of occlusion between the two guidance patterns since both occlusal guidance patterns were on the same splint for each subject. This could also explain some of the difference in the two studies' observations.

Much information about masticatory muscle function comes from the investigation of chewing cycles. Two major theories of neuromuscular control of mastication exist. The older suggests that chewing movements result from interaction of reflex systems. The newer theory suggests the existence of central neural control. An excellent overview of these is in a recent chapter by Luschei and Goldberg (1981). The following is only a brief review.

The reflex theory (figure #13) can be traced to Sherrington (1917) and is advanced by the work of Jerge (1964) and Kawamura (1967). It is supported as part of a more complex

Figure 13. Schematic representation of a hypothetical jaw reflex control system for mastication. As the jaw opens, the muscle spindles in the closer muscles excite the closer muscle motor neurons. The broken line indicates there may be very weak inhibition of the opener muscle motor neuron. As the teeth contact, the mechanoreceptors of the teeth (periodontal ligament receptors) excite the opener muscle motor neurons via the trigeminal sensory nucleus (TSN) and inhibit the closer muscle motor neurons. Rhythmic movement would result from alternation of these two reflex arcs. For simplicity's sake, inhibitory interneurons are not shown in the figure.


TRIGEMINAL MOTOR NUCLEUS
E
I
I
E
SPINDLE AFFERENT
JAW CLOSER MUSCLES
MOTOR AXON
(TSN)
PERIODONTAL & PULP AFFERENTS
E
MOTOR AXON
JAW OPENER MUSCLES

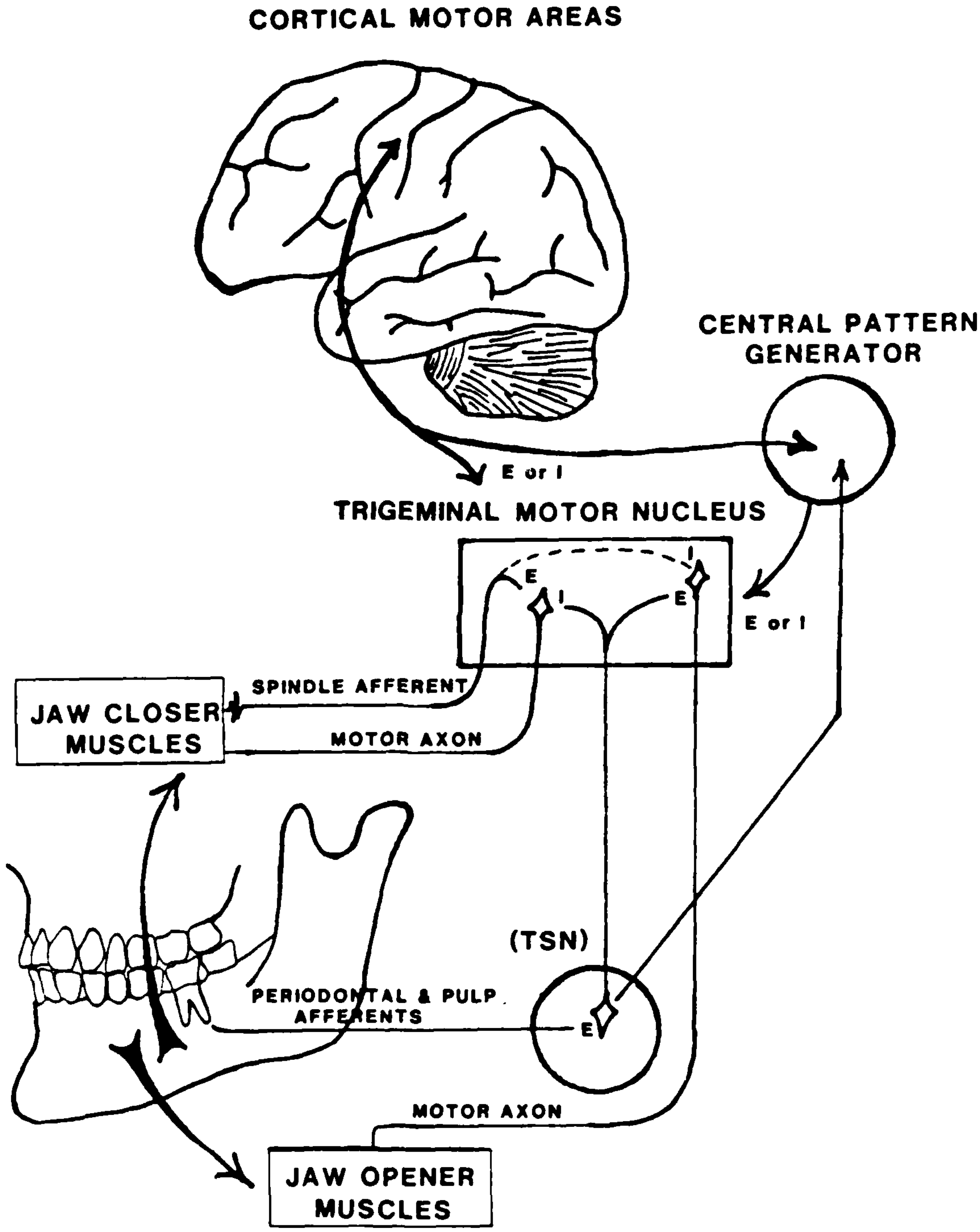
control mechanism by studies that show a peripheral receptor influence does exist (Yemm, 1972, Thexton, 1973, and Matthews, 1976). According to Sherrington's hypothesis, while the jaw is open, closing is initiated by stretch of the muscle spindle receptors of the closing muscles which make monosynaptic excitatory connections with the motoneurons of the closer muscles. There has been the assumption that despite excitation of jaw closer motoneurons there is simultaneous inhibition of jaw open motoneurons to permit jaw closing. However, in recent literature, studies indicate that there is simply absence of excitation in the opener motoneurons but little active inhibition (Lund and Olsson, 1983). This is sufficient to permit jaw closing to occur. As closure leads to occlusion the mechanoreceptors in the periodontal ligament (PDL) are excited. Through a multisynaptic pathway, this leads to reflex inhibition of motoneurons of closing muscles and to excitation of motoneurons to the jaw opening muscles, thus leading to jaw opening. The observed decreased EMG activity in the closing muscles seen in this study might be due to simple reflex inhibition from PDL mechanoreceptors. Experimental studies have shown that afferents from the muscle spindles fire in proportion to muscle stretch and those from the periodontal mechanoreceptors in proportion to biting force (Larson, Smith, and Luschei, 1981). Stimulation of the periodontal mechanoreceptors with the jaw at rest reflexly inhibits the jaw-closing muscles and activates the

digastric muscle for opening. While this type of peripheral input triggering alternating reflex opening and closing was previously felt to control the chewing movements, this may not be the main mechanism.

As noted in the Literature Review section, in the cat the canine does have a greater density of innervation than any other tooth in the cat (Michel, 1962, Eisenman, et. al., 1963, and Kawamura and Nishiyama, 1966) and in humans the canine has been shown to have the highest discriminatory ability for force detection of all teeth (Bonaguro, et. al., 1969). Yet in this present study the difference of peripheral input sources (mechanoreceptors in the canine or first molar PDLs) was not reflected in significantly different levels of EMG activity as measured. Had D'Amico's premise about the proprioceptive role of the canine been correct, it was expected that the canine would send a greater level of proprioceptive input and thus have a more magnified effect on the musculature. This failure to see a greater decrease in EMG activity with canine versus first molar guidance might be better explained by a more recent theory of the neuromuscular control of mastication.

While it has long been known that stimulation of the cortical motor area can produce repetitive movements of the jaw (Ferrier, 1886) later experiments suggest that the neurons

Figure 14. Schematic representation of a hypothetical brain-stem control system for mastication (modified from Lund and Olsson, 1983). This is where the main control of jaw movements is ascribed to central neural mechanisms. Here afferent information from the mechanoreceptors and muscle spindles may be overridden by input from the central pattern generator (CPG) in the brain stem which in turn may be influenced by higher centers such as the cerebral cortex or the amygdala in the limbic brain, as well as by oral sensory afferents. Rhythmic movement results from the CPG's input. For simplicity's sake, inhibitory interneurons are not shown in the figure.


CORTICAL MOTOR AREAS
CENTRAL PATTERN GENERATOR
E or I
TRIGEMINAL MOTOR NUCLEUS
E
I
I
E
E or I
SPINDLE AFFERENT
JAW CLOSER MUSCLES
MOTOR AXON
(TSN)
PERIODONTAL & PULP AFFERENTS
E
MOTOR AXON
JAW OPENER MUSCLES

responsible for the rhythmic movement are not cortical but confined to the brain stem or peripheral reflex pathway (Luschei and Goldberg, 1981). In this second theory of control of jaw movements central neural mechanisms play the dominant role and peripherally evoked reflexes can be suppressed or enhanced to varying degrees depending on the particulars of the jaw movement being executed (figure #14). In experiments with repetitive electrical stimulation of the motor cortex or descending corticobulbar pathways in rabbits Dellow and Lund (1971) noted bursts of electrical activity from the mylohyoid (opener) and masseteric (closer) motoneurons. These bursts corresponded in time to opening and closing movements of the jaw. They concluded a central pattern generator (CPG) is located in the reticular formation where a population of neurons generates the rhythm for mastication and drives the trigeminal motoneurons accordingly.

This CPG can be influenced not only by peripheral afferents but also by other central structures such as the cerebral cortex, elements of the pontine and medullary reticular formations, basal ganglia, motor thalamus, cerebellum and limbic areas (Hannam and Matthews, 1969). Lund and Olsson recently (1983) reviewed the case for a central control of jaw movements. They provided evidence showing that neural activity from central structures that generate jaw movements can depress transmission from the peripheral afferents thus suppressing reflexes that

could interfer with an intended movement. They measured oral reflex responses both in the presence and absence of mastication and observed that during mastication certain reflexes were suppressed but some nociceptive ones enhanced. Potentially damaging stimuli seem to be enhanced by the central control mechanisms to prevent damage or injury to oral tissue. Such modification of reflexes during mastication (evoked by stimulation of the CPG) occurred even during paralysis of jaw muscles when the responses of the nerves to jaw openers and closers were recorded rather than actual EMG activity.

The similar decreases in EMG activity seen with the two guidance patterns in this study might thus primarily result from central neural mechanisms that generate the studied movements. In which case neither source of peripheral inputs (canine or first molar mechanoreceptors) evidenced a distinctly different effect. Thus the observed reduction in EMG activity might be due primarily to central neural commands to relax the muscles to allow lateral movement or clenching in a lateral position. A more stringent test of this idea would be to repeat the jaw movements and clenching while the peripheral afferents are inactive (local anesthesia).

Extrapolation of these results into clinical splint practice must be tempered by the study's limitations. Some of

these limitations concern the subjects tested, the nature of the jaw movements tested, the inherent effect of a splint on the musculature and tooth proprioception, and which teeth were tested.

The measurements were taken in the laboratory on subjects who were healthy and not on patients actively seeking care for bruxism or facial pain. Further, no effort was made to analyze the effects of current mandibular plane angles, past orthodontic correction of skeletal malocclusion or any other factor not already stated that might effect jaw muscle EMG activity (DiPietro, Moergeli, 1976). Also the patterns of movement tested in this study were pure right lateral excursive movements. Because the patterns of movement in bruxism are not so restricted the results might be different in the natural environment of the bruxer or with a combination of jaw movements. It is possible that this more complex pattern would respond differently to testing. This possibility that the natural environment bruxism movement patterns might test differently is being evaluated in an ongoing clinical investigation at Wilford Hall USAF Medical Center.

Although this study could find no differences in EMG activity in lateral excursive clenching with canine guidance as opposed to first molar guidance one cannot conclude that canine

guidance is not clinically useful. There may yet be many reasons to use canine guidance. It may provide mechanical benefits that preserve the dentition thru the distribution of force (Dawson, 1974). Such distribution can result in an altered lever system to disperse the force application to teeth away from the powerful masseter muscle. It may result in non-mechanical benefits. Two such observed examples are improved tissue health (Goldstein, 1979) and less destruction to the investing periodontium (Youdelis and Mann, 1965). And while it may be easier to develop in the clinical setting because of better access, it may also be more feasible and appropriate for the more dynamic movements of natural environment bruxism. These beliefs however need to be tested by controlled experimentation.

The current study used a maxillary splint occluding against mandibular guidance. The maxillary splint is a major means of treating bruxism (Ramfjord and Ash, 1983, Clark, 1984) and was the means Williams and Lundquist used to test D'Amico's premise. One problem with using a splint to test this premise is that it joins the maxillary teeth together mechanically into one unit. The exact effect of this on the neurophysiology of jaw function is uncertain. However one effect might be decreased proprioception. Because a splint is made of firm plastic it displaces teeth during placement and wear. While this displacement is minimal it may be sufficient to have an effect.

Yamada (1967) found that the amount of displacement necessary to elicite a response from the teeth is very small. The magnitude of these displacements is similar to the displacement noted when a splint is seated. Indeed it is common for patients to comment upon the "tightness" of an appliance. This feeling passes as the splint is kept in place and the teeth accommodate to the light orthodontic forces. Nafkoor (1967) determined that proprioceptive ability is lowered significantly by the application of such light orthodontic forces on the teeth. Thus the splint itself might have had an effect upon any unique canine proprioception such as proposed by D'Amico. But it should be noted that any effect from the splint was present for both canine and first molar guidance patterns. Therefore if D'Amico's premise about the canine's increased proprioception is correct it would be expected to still be evident since both the canine and control guidance were altered by the same splint effects.

Another potential problem with the current study is that the splint occluded against the mandibular canine. D'Amico's initial premise of increased proprioception involved both the maxillary and mandibular canines (D'Amico, 1958). The application of his premise has generally involved the mandibular canine occluding against a maxillary splint (Ramfjord and Ash, 1971). However data that the maxillary canine is particularly sensitive to pressure could indicate some special

neurophysiologic relationship with the muscles of mastication (Bonaguro, et. al., 1969). Using individual maxillary teeth to provide the guidance would be a better means of testing D'Amico's premise. Such a model might use acid etch material to manipulate the maxillary lingual tooth contours to provide the guidance for excursive movement and clenching (Thayer and Doukoudais, 1981). Canine guidance thus might be contrasted with first molar guidance to test for a unique effect from the canine. Both patterns could then be compared to a group guidance from canine to first molar to also test the effect of an increased number of teeth. This possibility is currently under investigation at the University of Texas Health Science Center Dental School, San Antonio. However, it may still turn out that central motor mechanisms suppress the peripheral influences.

VI. SUMMARY

The present study found a reduction of anterior temporalis and masseter muscle EMG activity during both lateral excursive movement and excursive clenching on a maxillary splint. The average reductions during the movement phase were 81.8 ±14.0% with canine guidance and 81.6 ±19.2% with first molar guidance. The average reductions during the excursive clenching phase were 44.7 ±26.7% with canine guidance and 42.6 ±29.7% with first molar guidance. There was no statistically significant difference in the reductions of EMG activity for the two different guidance patterns.

In this study there was considerable variance in actual EMG scores between subjects. This intersubject variability was dealt with by a within subject design using percentage reductions of the EMG activity. These percentage reductions of EMG activity show that clenching during lateral movement reduced jaw muscle activity significantly more than clenching in excursive position for both guidance patterns.

The jaw muscle activity was observed to be reduced during lateral movement and excursive position clenching. There was no statistically significant difference in the degree of reduction

for either cuspid guidance or first molar guidance on a maxillary occlusal splint.

These results question the clinical premise (D'Amico, 1955, Ramfjord and Ash, 1981) that the cuspid possesses special neurophysiologic characteristics that offer advantages over other teeth for excursive guidance.

APPENDICES

TABLE A-1

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient #1 Age: 32 Sex: M
Guidance Sequence: Canine then First Molar.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	21.53	2.82	14.00	27.13	1.61	14.87
Rt. Temp.	23.37	2.92	13.23	25.17	1.49	14.50
Lt. Temp.	19.57	4.49	12.37	21.70	1.36	14.30
Lt. Mass.	17.28	6.25	12.72	25.87	1.91	15.50
SERIES 2						
Rt. Mass.	20.43	6.89	14.67	27.57	1.90	15.48
Rt. Temp.	20.83	8.08	15.77	30.12	1.76	17.70
Lt. Temp.	17.60	6.54	13.73	26.40	1.48	19.80
Lt. Mass.	16.30	7.70	14.77	28.00	1.61	20.27
SERIES 3						
Rt. Mass.	27.73	1.52	18.20	20.60	1.51	17.77
Rt. Temp.	28.20	1.39	20.90	23.47	1.33	17.78
Lt. Temp.	22.07	1.45	20.56	22.33	0.72	16.40
Lt. Mass.	24.57	2.31	20.20	25.00	1.24	20.47
SERIES 4						
Rt. Mass.	28.57	5.02	16.33	20.73	1.75	16.43
Rt. Temp.	27.87	6.13	13.10	22.80	1.72	15.77
Lt. Temp.	18.97	4.95	14.23	19.83	1.44	13.97
Lt. Mass.	22.13	6.17	15.63	23.67	1.65	16.80
SERIES 5						
Rt. Mass.	27.30	1.43	14.60	23.73	2.19	18.03
Rt. Temp.	27.27	1.39	14.30	24.00	2.04	17.73
Lt. Temp.	24.87	1.21	11.58	23.53	1.84	16.93
Lt. Mass.	26.10	2.99	13.70	26.43	2.28	18.40

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-2

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 2 Age: 23 Sex: F
Guidance Sequence: First Molar then Canine.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	24.27	4.48	11.19	24.03	3.09	2.69
Rt. Temp.	28.70	1.71	8.40	27.73	1.49	2.55
Lt. Temp.	36.77	0.97	16.67	36.50	2.21	14.50
Lt. Mass.	66.07	9.47	43.80	72.43	12.23	29.97
SERIES 2						
Rt. Mass.	33.10	16.47	12.21	22.33	1.27	5.92
Rt. Temp.	32.03	4.13	7.89	26.63	1.07	3.43
Lt. Temp.	41.20	1.95	15.57	35.77	2.81	21.37
Lt. Mass.	72.67	4.49	45.87	72.00	9.46	41.03
SERIES 3						
Rt. Mass.	24.21	9.90	8.64	23.06	3.29	5.76
Rt. Temp.	27.37	2.48	9.08	28.87	1.65	3.72
Lt. Temp.	33.70	2.25	17.87	35.70	2.49	20.49
Lt. Mass.	61.80	8.43	41.80	66.50	6.59	38.93
SERIES 4						
Rt. Mass.	30.27	13.70	10.67	24.67	3.04	5.58
Rt. Temp.	29.70	3.76	10.29	31.80	0.96	4.85
Lt. Temp.	36.30	1.84	16.70	38.40	2.00	20.40
Lt. Mass.	84.77	8.13	42.70	76.20	12.80	44.47
SERIES 5						
Rt. Mass.	22.63	12.67	9.05	20.83	2.08	10.77
Rt. Temp.	26.43	3.79	7.61	27.83	1.08	6.04
Lt. Temp.	36.43	3.00	18.73	32.30	2.80	23.43
Lt. Mass.	70.20	14.55	49.27	70.43	8.16	48.33

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-3

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 3 Age: 30 Sex: F
Guidance Sequence: Canine then First Molar.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
	clench	movement	clench	clench	movement	clench
SERIES 1						
Rt. Mass.	58.03	23.37	24.10	41.20	22.53	39.43
Rt. Temp.	40.17	3.00	14.45	24.11	1.87	6.92
Lt. Temp.	31.63	9.94	28.83	16.06	4.20	13.83
Lt. Mass.	57.23	4.23	26.33	43.90	4.91	22.37
SERIES 2						
Rt. Mass.	61.60	21.30	39.63	56.83	4.47	20.60
Rt. Temp.	35.87	2.73	23.33	37.37	1.80	13.23
Lt. Temp.	32.70	7.93	34.23	26.00	2.96	8.58
Lt. Mass.	42.63	6.27	36.13	40.67	5.8	18.69
SERIES 3						
Rt. Mass.	64.03	19.77	23.77	57.50	8.87	20.00
Rt. Temp.	39.00	1.75	21.80	43.13	1.91	12.90
Lt. Temp.	20.75	5.53	30.10	23.39	1.96	12.03
Lt. Mass.	43.93	3.79	36.00	43.63	2.56	23.23
SERIES 4						
Rt. Mass.	70.73	29.23	30.27	41.77	16.10	28.07
Rt. Temp.	50.27	2.32	25.40	33.27	1.45	7.73
Lt. Temp.	35.97	7.51	30.23	20.83	2.65	10.25
Lt. Mass.	61.70	4.24	34.87	39.50	2.80	21.93
SERIES 5						
Rt. Mass.	63.66	23.00	31.37	60.20	16.43	24.90
Rt. Temp.	44.67	1.95	26.80	46.77	2.47	10.04
Lt. Temp.	35.50	5.79	34.27	32.50	2.59	9.28
Lt. Mass.	50.00	3.40	39.83	53.73	3.00	21.40

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-4

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 4 Age: 26 Sex: M
Guidance Sequence: First Molar then Canine.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	28.77	1.41	8.88	32.00	1.33	16.28
Rt. Temp.	23.37	1.25	2.07	30.70	1.88	3.21
Lt. Temp.	12.53	4.19	8.41	22.27	5.20	22.80
Lt. Mass.	10.77	1.05	7.29	36.90	1.76	9.19
SERIES 2						
Rt. Mass.	39.27	2.20	10.12	33.93	2.41	18.60
Rt. Temp.	32.87	1.32	2.12	30.03	1.81	4.35
Lt. Temp.	23.97	7.95	11.40	26.03	11.34	22.73
Lt. Mass.	14.80	1.53	7.68	11.99	14.23	10.91
SERIES 3						
Rt. Mass.	32.97	1.33	11.03	25.57	2.29	3.88
Rt. Temp.	27.70	1.08	2.92	29.73	1.41	1.40
Lt. Temp.	19.17	9.35	10.71	19.83	6.20	18.03
Lt. Mass.	11.99	2.05	6.31	11.39	1.18	6.89
SERIES 4						
Rt. Mass.	31.20	1.61	14.63	28.43	1.53	8.57
Rt. Temp.	28.00	1.47	4.97	28.63	1.44	2.55
Lt. Temp.	15.77	7.27	10.97	14.74	5.17	25.13
Lt. Mass.	12.87	2.96	7.49	10.80	1.56	9.49
SERIES 5						
Rt. Mass.	28.40	1.17	11.73	25.88	1.11	6.87
Rt. Temp.	27.77	0.85	2.71	28.39	0.78	1.39
Lt. Temp.	14.91	5.91	14.83	16.19	8.43	14.73
Lt. Mass.	10.69	2.48	6.49	10.16	1.43	7.09

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-5

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 5 Age: 25 Sex: F
Guidance Sequence: Canine then First Molar.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	12.73	1.21	11.61	9.08	2.00	8.11
Rt. Temp.	32.10	4.16	31.73	21.80	10.89	25.40
Lt. Temp.	24.60	0.72	20.50	19.33	0.43	0.63
Lt. Mass.	14.73	1.28	12.60	16.57	1.65	10.10
SERIES 2						
Rt. Mass.	7.51	2.8	6.63	14.13	4.53	13.20
Rt. Temp.	4.63	2.81	3.57	30.37	22.63	32.90
Lt. Temp.	6.19	1.21	2.05	7.63	0.72	1.41
Lt. Mass.	17.17	5.25	14.10	17.47	5.84	14.00
SERIES 3						
Rt. Mass.	11.65	2.43	8.24	8.84	2.51	8.43
Rt. Temp.	28.50	5.71	18.53	21.97	16.17	22.30
Lt. Temp.	20.80	0.61	10.03	7.33	0.53	1.36
Lt. Mass.	15.03	3.67	12.97	16.97	5.60	12.33
SERIES 4						
Rt. Mass.	6.99	1.04	6.63	8.37	2.21	9.18
Rt. Temp.	19.60	6.33	6.79	28.77	17.50	23.37
Lt. Temp.	21.67	0.59	11.51	23.93	0.75	1.49
Lt. Mass.	16.63	5.01	13.47	13.97	3.19	11.13
SERIES 5						
Rt. Mass.	6.29	1.01	6.25	7.99	1.97	7.77
Rt. Temp.	7.17	5.09	5.56	22.80	15.00	28.13
Lt. Temp.	5.23	0.96	2.53	5.32	0.73	0.96
Lt. Mass.	13.67	5.41	13.33	13.20	3.40	8.89

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-6

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 6 Age: 30 Sex: M
Guidance Sequence: Canine then First Molar.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	42.13	2.83	4.95	34.17	2.89	7.79
Rt. Temp.	58.67	8.49	27.90	53.33	6.75	19.30
Lt. Temp.	48.97	2.89	5.78	41.47	0.76	4.32
Lt. Mass.	58.53	5.87	16.57	52.93	8.23	21.83
SERIES 2						
Rt. Mass.	33.03	1.93	4.35	46.70	2.98	9.51
Rt. Temp.	51.30	7.27	16.10	52.83	9.91	22.33
Lt. Temp.	44.10	0.60	14.13	35.20	1.09	1.29
Lt. Mass.	53.50	3.19	15.63	69.63	10.03	18.90
SERIES 3						
Rt. Mass.	38.83	2.25	5.79	33.63	3.03	8.40
Rt. Temp.	51.23	7.36	14.90	47.10	7.52	23.20
Lt. Temp.	48.10	2.48	3.76	32.07	0.64	0.80
Lt. Mass.	56.57	4.40	17.97	52.97	12.31	27.73
SERIES 4						
Rt. Mass.	37.57	2.52	5.83	36.70	4.28	7.81
Rt. Temp.	53.63	8.36	10.60	52.83	9.65	20.30
Lt. Temp.	46.50	0.84	3.56	34.30	1.01	3.38
Lt. Mass.	53.17	6.57	18.80	56.40	10.40	22.77
SERIES 5						
Rt. Mass.	30.43	1.67	4.59	38.27	4.72	9.03
Rt. Temp.	35.95	5.75	9.12	49.10	6.76	20.10
Lt. Temp.	33.43	0.60	1.23	36.27	0.96	2.24
Lt. Mass.	46.03	4.23	15.90	61.87	13.03	25.77

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-7

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 7 Age: 24 Sex: F
Guidance Sequence: First Molar then Canine.

	Canine Guidance			Molar Guidance		
	clench	movement	clench	clench	movement	clench
SERIES 1						
Rt. Mass.	47.04	10.94	39.50	79.10	37.85	78.43
Rt. Temp.	105.37	30.04	88.33	110.67	34.55	100.97
Lt. Temp.	86.40	28.90	65.67	102.47	16.62	93.50
Lt. Mass.	78.10	15.38	68.70	104.67	19.18	91.13
SERIES 2						
Rt. Mass.	44.30	4.97	42.67	103.07	21.85	66.50
Rt. Temp.	103.07	21.85	66.50	109.67	52.37	94.00
Lt. Temp.	92.20	20.99	48.27	103.70	62.83	82.00
Lt. Mass.	79.93	15.29	49.90	101.73	26.93	90.60
SERIES 3						
Rt. Mass.	69.90	17.60	52.80	84.23	25.10	65.97
Rt. Temp.	95.10	25.01	89.83	111.00	35.33	87.30
Lt. Temp.	93.70	17.17	81.43	105.47	30.23	90.33
Lt. Mass.	93.96	11.58	85.77	99.93	18.87	87.60
SERIES 4						
Rt. Mass.	75.17	13.69	68.07	94.17	27.71	59.87
Rt. Temp.	104.77	33.32	104.00	121.33	50.10	79.93
Lt. Temp.	107.57	34.19	97.20	133.67	66.73	83.30
Lt. Mass.	81.17	18.50	90.73	101.10	23.63	79.03
SERIES 5						
Rt. Mass.	81.23	27.57	88.07	75.27	22.46	74.03
Rt. Temp.	108.20	20.47	105.83	108.33	48.33	100.93
Lt. Temp.	120.67	42 03	92.73	105.13	67.40	100.43
Lt. Mass.	109.67	25.77	88.67	95.47	36.13	93.30

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-8

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 8 Age: 26 Sex: F
Guidance Sequence: Canine then First Molar.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	49.50	13.50	33.87	47.07	13.29	36.93
Rt. Temp.	27.23	4.61	8.99	25.73	7.03	12.57
Lt. Temp.	34.63	8.19	16.50	32.93	13.27	24.90
Lt. Mass.	53.80	0.93	5.12	43.90	3.92	29.20
SERIES 2						
Rt. Mass.	39.43	19.40	23.60	46.63	20.47	38.37
Rt. Temp.	25.20	7.91	9.93	28.03	7.83	13.07
Lt. Temp.	34.90	7.48	16.87	37.87	8.97	26.43
Lt. Mass.	43.97	1.09	5.64	48.43	4.11	31.80
SERIES 3						
Rt. Mass.	28.30	16.73	28.07	41.17	15.99	34.50
Rt. Temp.	21.00	7.61	13.53	26.63	4.16	11.31
Lt. Temp.	28.77	14.23	24.17	41.37	14.20	18.50
Lt. Mass.	47.40	1.73	7.00	46.33	4.68	14.42
SERIES 4						
Rt. Mass.	27.23	12.60	27.16	43.33	10.47	32.07
Rt. Temp.	24.47	4.76	11.27	22.20	28.40	17.23
Lt. Temp.	31.50	10.55	18.17	36.00	5.91	21.40
Lt. Mass.	43.80	1.00	8.55	39.13	0.71	16.73
SERIES 5						
Rt. Mass.	41.77	15.93	25.50	49.13	23.53	35.53
Rt. Temp.	22.90	6.49	13.40	20.96	18.60	12.10
Lt. Temp.	31.00	10.97	22.07	40.20	19.33	19.60
Lt. Mass.	35.70	1.23	10.23	55.40	3.49	27.79

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-9

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 9 Age: 25 Sex: M
Guidance Sequence: First Molar then Canine.

	Canine Guidance			Molar Guidance		
	clench	movement	clench	clench	movement	clench
SERIES 1						
Rt. Mass.	74.20	6.67	32.27	51.70	10.67	56.73
Rt. Temp.	65.60	7.85	26.90	44.00	14.97	43.50
Lt. Temp.	49.40	1.95	13.67	41.63	2.49	33.77
Lt. Mass.	31.80	2.93	6.17	27.70	2.28	13.84
SERIES 2						
Rt. Mass.	75.67	12.43	42.03	55.20	16.41	53.13
Rt. Temp.	60.23	11.03	36.03	52.37	12.93	41.73
Lt. Temp.	57.90	1.95	21.53	50.47	2.60	37.70
Lt. Mass.	36.60	2.76	13.87	28.37	1.52	14.50
SERIES 3						
Rt. Mass.	76.23	14.91	29.97	50.60	12.97	45.73
Rt. Temp.	54.40	10.81	28.67	48.83	8.69	43.67
Lt. Temp.	57.30	2.32	14.20	47.87	1.71	36.70
Lt. Mass.	31.77	2.07	16.63	25.70	1.99	24.90
SERIES 4						
Rt. Mass.	58.70	19.20	43.63	62.63	18.07	45.00
Rt. Temp.	54.83	12.23	37.43	48.57	8.45	43.10
Lt. Temp.	47.77	2.69	18.93	47.53	2.19	19.97
Lt. Mass.	32.57	2.05	8.29	29.40	1.68	16.13
SERIES 5						
Rt. Mass.	69.23	23.23	46.37	61.77	15.55	55.90
Rt. Temp.	54.97	16.92	38.57	53.03	10.95	39.23
Lt. Temp.	49.63	5.52	19.77	49.53	2.40	27.27
Lt. Mass.	32.93	1.55	9.93	30.10	1.96	6.84

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

TABLE A-10

MEAN EMG SCORES DURING CLENCHING
IN CENTRIC, MOVEMENT TO EXCURSIVE, AND EXCURSIVE POSITIONS
FOR INDIVIDUAL MUSCLES WITH EACH GUIDANCE PATTERN
[1 UNIT = 2.5 MV-SEC]

Patient # 10 Age: 26 Sex: F
Guidance Sequence: First Molar then Canine.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	26.50	5.15	17.37	30.83	1.79	15.63
Rt. Temp.	38.70	4.63	14.70	40.13	1.93	22.17
Lt. Temp.	39.77	0.80	12.46	50.77	3.08	39.70
Lt. Mass.	41.73	0.53	4.07	42.77	0.44	2.70
SERIES 2						
Rt. Mass.	31.10	5.89	18.50	33.73	1.83	10.50
Rt. Temp.	37.67	6.37	18.37	39.70	3.21	18.33
Lt. Temp.	54.47	4.65	23.47	54.20	2.57	24.33
Lt. Mass.	51.30	0.80	3.28	53.10	0.53	1.16
SERIES 3						
Rt. Mass.	30.43	8.29	21.43	32.63	3.12	18.57
Rt. Temp.	44.40	7.61	28.80	38.60	3.36	22.20
Lt. Temp.	56.07	7.23	23.70	50.47	4.04	40.70
Lt. Mass.	50.03	0.88	3.55	42.40	0.54	4.19
SERIES 4						
Rt. Mass.	33.43	5.09	23.97	28.50	3.92	16.27
Rt. Temp.	39.60	5.33	23.83	43.13	4.28	25.50
Lt. Temp.	56.43	9.42	41.17	54.40	4.77	36.93
Lt. Mass.	40.37	0.81	12.81	52.87	0.68	2.41
SERIES 5						
Rt. Mass.	24.40	6.08	21.67	29.50	6.04	15.53
Rt. Temp.	35.60	5.24	25.73	38.77	6.16	22.41
Lt. Temp.	53.03	15.12	48.20	50.70	4.39	38.37
Lt. Mass.	50.87	1.11	14.03	47.77	2.95	3.36

Rt.=Right; Lt=Left; Mass.=Masseter; Temp.=Temporalis

Appendix B: Calculation of Percentage Reductions

The percentage reductions were calculated as ratios by the following formulas.

C = EMG score during clenching in centric occlusion

M = EMG score during movement to excursive occlusion

E = EMG score during clenching in excursive occlusion

c indicates canine guidance

m indicates first molar guidance

#1 ---- [(Cc - Mc)/Cc][100] = EMG percent reduction during movement on canine guidance

#2 ---- [(Cm - Mm)/Cm][100] = EMG percent reduction during movement on molar guidance

#3 ---- [(Cc - Ec)/Cc][100] = EMG percent reduction during excursive clenching with canine guidance

#4 ---- [(Cm - Em)/Cm][100] = EMG percent reduction during excursive clenching with molar guidance

These ratios were calculated with the DEC VAX 11 computer. The raw data for a sample calculation is from patient #1. The calculations are for ratios #1-4 for Series 1 data from the right masseter muscle.

	Canine Guidance clench-movement-clench			Molar Guidance clench-movement-clench		
SERIES 1						
Rt. Mass.	21.53	2.82	14.00	27.13	1.61	14.87
Rt. Temp.	23.37	2.92	13.23	25.17	1.49	14.50
Lt. Temp.	19.57	4.49	12.37	21.70	1.36	14.30
Lt. Mass.	17.28	6.25	12.72	25.87	1.91	15.50

Ratio #1:

[(21.53 - 2.82)/21.53] [100] = 86.90% reduction

Ratio #2:

$$[(27.13 - 1.61)/27.13] [100] = 94.07\% \text{ reduction}$$

Ratio #3:

$$[(21.53 - 14.00)/21.53] [100] = 34.97\% \text{ reduction}$$

Ratio #4:

$$[(27.13 - 14.87)/27.13] [100] = 45.19\% \text{ reduction}$$

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Vita

Garbeth Sheldon Graham was born on March 25, 1951, in Fort Leonardwood, Missouri. Graduating from Lyon's Township High School, LaGrange, Illinois, in June 1969, he attended Rice University, Houston, Texas for two years before transferring to the University of Minnesota School of Dentistry, Minneapolis, Minnesota, in September 1971. From the University of Minnesota he received a Bachelor of Science degree in June 1973 and Doctor of Dental Surgery degree in June, 1975. Following graduation he began a hospital based two year General Dentistry Residency at Charity Hospital, New Orleans, Louisiana, in association with Louisiana State University School of Dentistry. The residency was completed in June 1977. He then entered the private practice of dentistry in association with M. W. Lockard, Jr., D.D.S. of Oklahoma City, Oklahoma. During this time he was on the part time teaching staff of St Francis Hospital. In October, 1978, he joined the United States Air Force and was assigned to Wilford Hall USAF Medical Center, San Antonio, Texas. While there he taught in the General Dentistry Residency. In July, 1983, he enrolled in the Periodontic Post-Doctoral Program at the University of Texas Health Science Center at San Antonio in conjunction with Wilford Hall USAF Medical Center. He was admitted to candidacy for the Master of Science degree at the Graduate School in April, 1983. He was married to Maureen C.

Cunnion on March 24, 1973. They have two sons. Ross Francis was born on June 4, 1980 and Hudson Daniel on March 8, 1984. His parents, Judge Garbeth C. Graham and Ann M. Graham, both currently reside in Oklahoma City, Oklahoma.

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